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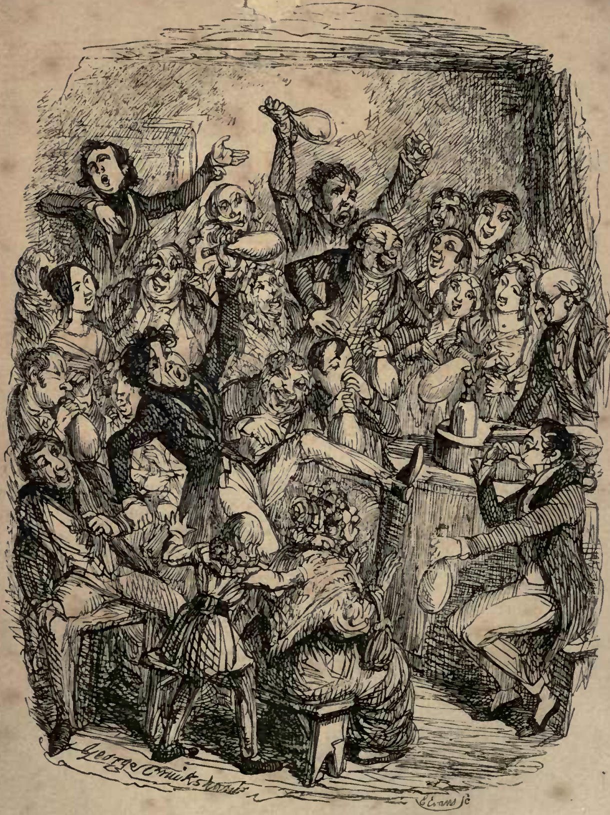


Laughing Gas.

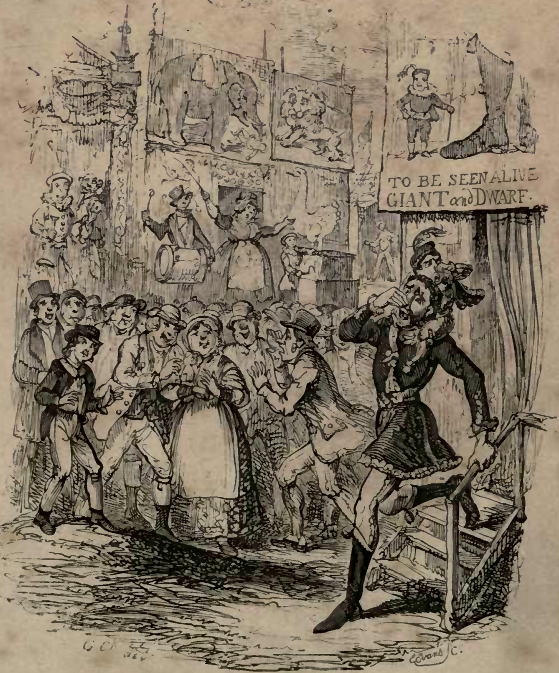
"Some jumped over the tables and chairs; some were bent upon making speeches; some were very much inclined to fight."

Page 116.

Chemistry no Mystery;

OR,

A LECTURER'S BEQUEST.



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CHEMISTRY NO MYSTERY;

OR,

A LECTURER'S BEQUEST.

BEING THE SUBJECT-MATTER OF

A COURSE OF LECTURES,

Delivered by an Old Philosopher,

AND TAKEN IN SHORT-HAND BY ONE OF THE
AUDIENCE, WHOSE NAME IS NOT KNOWN.

Arranged from the Original Manuscript, and Revised,
BY
JOHN SCOFFERN,
SURGEON; AND LATE ASSISTANT CHEMIST AT THE LONDON HOSPITAL,
AND ALDERSGATE SCHOOL OF MEDICINE.

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TO HER GRACE

THE

DUCHESS OF NORTHUMBERLAND,

These Pages

ARE RESPECTFULLY INSCRIBED,

BY HER OBEDIENT SERVANT,

JOHN SCOFFERN.

CONTENTS.

Preface ix

LECTURE I.—Page 1.

Introduction—Meaning of the term Chemistry—Examples of Chemical Operations—Sketch of the History of Chemistry.

LECTURE II.—Page 10.

About the Imponderables, or Things which have no Weight.

LECTURE III.—Page 25.

Explanation of what is meant by the term *Weight*—Ponderable Bodies, or those which possess *Weight*—Specific Gravity.

LECTURE IV.—Page 32.

Oxygen.

LECTURE V.—Page 46.

Nitrogen—Hydrogen.

LECTURE VI.—Page 65.

Chlorine.

LECTURE VII.—Page 75.

Carbon.

LECTURE VIII.—Page 85.

Sulphur—Selenium—Phosphorus—Boron—Silicon.

LECTURE IX.—Page 91.

Compounds of the non-metallic simple Substances with each other—Oxygen and Nitrogen.

LECTURE X.—Page 108.

Protoxide of Nitrogen—Otherwise called Nitrous Oxide, or Laughing-Gas

LECTURE XI.—Page 117.

Binoxide of Nitrogen, or Nitric Oxide—Hyponitrous Acid—Nitrous Acid—Nitric Acid.

LECTURE XII.—Page 124.

Compounds of Hydrogen and Oxygen—Water, Peroxide of Hydrogen.

LECTURE XIII.—Page 142.

Compounds of Oxygen with Chlorine—Iodine—Bromine—Carbon, Carbonic Oxide, Carbonic Acid.

LECTURE XIV.—Page 158.

Compounds of Oxygen with Sulphur. Hypo-sulphurous Acid; Sulphurous Acid; Hypo-sulphuric Acid; Sulphuric Acid. Compounds of Oxygen with Selenium—Phosphorus—Boron and Silicon.

LECTURE XV.—Page 164.

Compound of Nitrogen with Hydrogen—(Ammonia)—with Chlorine—Iodine—Carbon.

LECTURE XVI.—Page 171.

Compounds of Hydrogen with Chlorine—Iodine—Bromine—Fluorine—Carbon—Sulphur—Selenium—Phosphorus.

LECTURE XVII.—Page 200.

Metals.

LECTURE XVIII.—Page 232.

Substances which are formed by the union of Compounds with each other.

LECTURE XIX.—Page 250.

Analytical Chemistry—Toxicology, or the Chemistry of Poisons.

LECTURE XX.—Page 264.

Remarks on Gravitation, Cohesion, and Affinity—Single and double Elective Affinity—Single and Double Decomposition.

LECTURE XXI.—Page 271.

Introduction to Organic Chemistry—Differences existing between the structure of Organized and Inorganized Bodies—Difference between Animals and Vegetables—Proximate Vegetable Principles.

CORRIGENDA.

Page 6, line 22, *for* fifty-five *read* fifty-four.
— 31 — 8 — ditto — ditto.
— 62 — 26 — one — five.

PREFACE.

The unknown author of these manuscripts relates the circumstances connected with the first origin of a literary and scientific institution, somewhere in Devonshire, after the manner of that at Arcueil, in France.

In the most lovely part of the southern coast of Devonshire is my native village; which, on account of the purity of its air, and the beauty of its surrounding scenery, has long been known as a favourite resort for invalids. Visitors we had many, but *strangers* none; hospitality having long banished the word from our vocabulary: or if *some* had considered themselves in that light on their first arrival, a few days' residence amongst us soon induced them to alter their minds, and made them feel quite at home. This state of society naturally brought with it many pleasures, but also much that was sad; for the circumstances that enabled us to find new friends also contributed to make us lose them; and many were our regrets for the departure of those whom, probably, we should see no more.

But of all our visitors one holds a pre-eminent seat in my memory, as having conferred on us a great and lasting benefit. He was an infirm and care-worn old man, whose mind, however, enjoyed its primary vigour, while his body was fast sinking under the weight of disease, and old age. What had been his avocations I know not, but he was thoroughly acquainted with scientific information, and delighted in imparting it to those around him, and on this account we gave him the name of the Old Philosopher.

It was during a walk which he took with us one morning along the beach, that his conversation turned on the re-establishment of peace;

for I should remark, the French revolutionary wars had just ceased. He proceeded to inform us that the French literary and scientific men had established, at a village named *Arcueil*, a philosophic institution, from which great benefits would most probably accrue to every department of learning. "One can hardly imagine," said he, "that so many highly talented men will concentrate their energies into one focus without producing some great and important results. For my own part, I am very sanguine that their scheme will meet with all the success it deserves, and I think their example should be very generally followed. Indeed I should much like to establish such an institution in this very place, and if my friends will support me in the undertaking it shall forthwith be done."

The old gentleman now ceasing for an instant, gave a penetrating glance at our features, to see if we accorded with his proposal; and, without waiting for an answer, because he said by the expression of our faces that we were delighted at the idea, he immediately replied, "Then let us commence to-morrow; I engage to furnish you with a room, and to deliver the first course of Lectures, which shall be on Chemistry."—On the morrow we met, each of us prepared with a note-book, for the purpose of taking extracts; and one of our party, who wrote short-hand, actually managed to copy almost verbatim the greater part of our Lecturer's discourse.

Such, then, was the origin of our little Philosophic Institution, which for many years flourished well. Season after season its founder returned and added to our fund of information; but death at length removed our benevolent old friend from the scene of his earthly labours; time and circumstances drove us from our early homes to mix in the busy scenes of active life; each passing year witnessed the gradual decline of our little society, and now it exists no more.

Such is the commencement of an original manuscript, which, together with the extracts alluded to, are now in the editor's possession, and from which the following Lectures have been arranged. How he obtained the precious documents it is scarcely necessary to tell;—should his young friends think it worth their while, they may exercise their ingenuity by an investigation of the subject.

Although the editor does not consider it necessary to state by what means the materials of the following Lectures were obtained; he begs leave to remark, that he, himself, is interested in their success, and will be delighted if they render the science of chemistry at all more accessible to youthful minds.

Should the following Lectures meet with approbation, there are more of them on other subjects, which at some future period may be arranged for the youthful public, by

Their ever obedient Servant,

JOHN SCOFFERN.

CHEMISTRY NO MYSTERY.

LECTURES ON CHEMISTRY.

LECTURE I.

INTRODUCTION—MEANING OF THE TERM CHEMISTRY—EXAMPLES OF CHEMICAL OPERATIONS—SKETCH OF THE HISTORY OF CHEMISTRY.

MY DEAR YOUNG FRIENDS,

If I were to present myself before you with an offer to teach you some new game:—if I were to tell you an improved plan of throwing a ball, of flying a kite, or of playing at leap-frog, oh, with what attention you would listen to me. Well, I am going to teach you many new games. I intend to instruct you in a science full of interest, wonder, and beauty; a science that will afford you amusement in your youth, and riches in your more mature years.

In short, I am going to teach you the science of chemistry.

Chemistry! I think I hear you repeat with a sneer—chemistry! Then we must make our faces and hands black with charcoal, burn our clothes into holes with oil of vitriol, and work ourselves into a fever with the exertion of blowing a great pair of bellows. No such thing. I grant, that in former times it was thought necessary to the successful study of chemistry, that one should have a large collection of instruments, such as furnaces, stills, and crucibles; besides an immense number of others, whose uncouth names almost make a person laugh; but such is not necessary now; and indeed I may mention, that one of the greatest chemists of the present century, I mean Dr. Wollaston, had so few instruments, and those so very small, that he kept them all in a common tea-tray. As for furnaces, they are only necessary to persons who study chemistry more as a matter of profit than of science. A melter of brass would employ a furnace, because he operates on large quantities; but I shall teach you how to melt brass with the flame of a common candle. This, however incredulous you may be of what I tell you, is really very easy to be done. I hope, then, I have convinced you that a person may study chemistry without soiling his face or hands, without burning himself, and without great bellows and furnaces. But still you may imagine that its comprehension may be too difficult. You do not understand the meaning of the term chemistry, and you think that young people cannot possibly engage themselves in the study of a science which has been cultivated by such great men as Sir Humphry Davy and Doctor Wollaston;—this supposition is wrong. I grant that the very highest order of intellect is often required to make a discovery; but when once made it may perhaps be rendered comprehensible to persons much younger than yourselves; and indeed I cannot think of any necessary portion of chemical science, which does not admit of a very easy and agreeable exemplification.

Before commencing the study of any science, it is usual, in systematic books, to explain the meaning of terms; and I might explain or define to you the meaning of the term chemistry; but as I do not like mere definitions without instances, let me give you a few cases of chemical operations. I fear you will laugh at their simplicity, but never mind that. To begin then. Suppose you had some wet sand, and wished to dry it, how would you proceed? My question amuses you I dare say, but I have very little doubt that you cannot give me the reason of all you do, even in the simple operation of drying sand. *I* know very well how you would proceed. You would put a plate over the fire, and on this plate you would place the sand; presently steam would arise, and the sand would become dry; but just at this period crack would go the plate. Now, my young philosophers, you laughed at my asking you so simple a question as how to dry sand, and I will avenge myself by demanding the why and the wherefore of all that has occurred. Why did the process of heating the sand cause the water to fly off in steam? Why did the plate break? Ah! you cannot answer me. Now in drying sand, you have performed a chemical operation, and if you knew chemistry you would be enabled to offer an explanation of all that has occurred. We will have two or three instances more, if you please.

Some time since a lady fancied that her moist-sugar contained an impurity: what it was she could not tell, but she knew by its taste that some improper substance was mixed with it.

In order to satisfy herself on this point she sent some for examination to a gentleman who understood chemistry, and this gentleman proved most satisfactorily that the sugar was mixed with salt. Now I will tell you how he proceeded to discover this. Sugar is capable of being dissolved in spirits-of-wine, but salt is not; he therefore boiled the lady's sugar with spirits of wine, and having done this, he found that something remained behind, which the spirits of wine would not dissolve. This something he proved to be salt.

I will give you another instance of a chemical operation, in which indeed I was personally concerned. About two months ago I was near witnessing the death of a much-valued friend, by poisoning, from a preparation of copper. He had just eaten some pickles, when suddenly he became so very sick and ill, that I at once suspected he had been poisoned. On looking at the pickles, (which appeared *very* green,) my suspicions were strengthened, and I immediately settled all doubts, by pouring on some of the suspected pickle a little hartshorn, when immediately there was produced a beautiful blue colour. Now I knew that nothing but copper could have done this, and I therefore immediately attended to my friend, to whom I administered some white of egg, beaten up with water, and by this treatment I probably saved his life. Here then you have *two* instances of chemical operations—that of hartshorn striking a blue colour with the preparation of copper, and that of the white of egg in destroying its poisonous action. By this time I think you must have some idea of the nature and value of chemical knowledge.

I dare say you would like to know something about the history of chemistry, and in order to gratify your curiosity, I will give you a short account of its commencement and progress. The ancient Greeks and Romans knew very little of chemistry, as indeed I shall soon convince you. Every one has heard of the four elements,—fire, air, earth, and water; those were the four elements of the ancients, and of which they believed that every thing was composed. Now modern chemists have shown, that instead of four elements there are in reality fifty-five, consequently you may imagine how very little the ancient Greeks and Romans knew about the science.

Chemistry first originated in Arabia, and the celebrated Haroun Alraschid, whom you have so frequently read of in the Arabian Tales, himself admired and cultivated it. Geber and

Avicenna were two great Arabian chemists, whose works remain to the present day.

The Arabians were a very warlike race, and having subdued all the nations on the northern coasts of Africa, they crossed over into Spain, A. D. 712, the greater part of which nation they conquered, after a severe struggle, and from which they were not expelled until the year 1492. The Arabians carried with them, into Spain, their fondness for scientific learning, and from this nation was chemistry diffused over Europe. After the learning of the Arabians had spread beyond the boundaries of Spain, there arose a celebrated class of men called alchemists. Most persons have heard of the alchemists, and I here present you with the picture of one.

An old man sitting amongst a heap of bottles, stills, fire-shovels, and other instruments, apparently engaged in deep thought, and most likely bent on the preparation of some mystic compound.

I need not tell you what the object of the alchemist was to accomplish, for you are well aware that his business, if I may so term it, was to make gold, and to prepare a medicine which should render man immortal. Roger Bacon, who lived in the thirteenth century, affirmed that an alchemist, named Artephius, died in his time, at the very advanced age of *one thousand and twenty-five years!* having prolonged his life to this good old age by the miraculous power of his medicines. If this be true, Artephius must have seen the world in a very early state, and the antiquity of alchemy must indeed be great; but unfortunately for the credit of this worthy old man, history has been pleased to fix the date at which the first European alchemist ever lived, as late as the eleventh century, and even the commencement of the art no earlier than the fifth.

One of the alchemists, named Paracelsus, was impudent enough to say that he could live as long as he liked; but in spite of this boast he died at the comparatively early age of forty-two.

I need not tell you that the alchemists never succeeded in their endeavours to make gold, and to prevent people from dying; on the contrary, they were generally poor themselves, and for the most part died at untimely periods of life. After the dark ages had ceased, and people began to make more use of their reasoning faculties, the alchemists got well laughed at, as indeed they deserved to be; consequently, instead of trying to make gold, and to prepare a medicine which should render people immortal, those who studied the science began to apply their knowledge to real advantage; and now the term alchemy was changed to chemistry. This, my young friends, is a very slight sketch of the *history* of chemistry, and in our next Lecture we will, if you please, enter upon the *scientific* part of our undertaking.

LECTURE II.

ABOUT THE IMPONDERABLES, OR THINGS WHICH HAVE NO WEIGHT.

PERHAPS my hearers will startle a little, when I tell them I am going to describe the nature of the *imponderable agents. Imponderable!*—what a long word! Well, I grant that imponderable *is* a long word, but nevertheless a very easy word to understand; it merely means something which has no weight. If I were to give you a pair of scales and weights, and tell you to weigh a spoon, a fork, or a poker, you could do so easily enough; but how you would laugh if I were to tell you to weigh a sun-beam, or the light of a candle, or the heat which is given out by the fire. It would be a ridiculous request for me to make indeed, and I merely suppose myself doing so, just to fix a fact in your memory. Light and heat cannot be weighed, neither can another substance, termed electricity.—Consequently

LIGHT,
HEAT,
ELECTRICITY

are imponderables.

Now the sources of light are various, but the greatest of all is the sun. Light takes about eight minutes to pass from the sun to the earth, a distance of nearly ninety-five millions of miles, travelling therefore with the immense velocity of two hundred thousand miles in a second of time! Whereas a cannon-ball, when it first leaves the mouth of the gun, takes three seconds to travel one mile; and if it could continue its course with undiminished rapidity, it would occupy ten years in reaching the sun! These facts will awaken in your mind feelings of wonder and admiration for that Great Being who had the power to create a substance so mysterious. You may, perhaps, think me wrong in calling light a substance, but one is obliged to do so for want of a better term.

Although we are aware of the rapidity with which light travels, and although we know that it is the cause of vision, yet there is a difficulty experienced in determining the actual nature of light. Sir Isaac Newton believed that it consisted of small particles continually darted away from luminous bodies, and which, by falling on the delicate nerve of the eye, with a certain force, produced vision. This philosopher imagined that the particles of which I speak were not all of the same size; those producing red light being largest, and those producing violet light smallest. But this theory has, in great measure, given way to another, according to which it is imagined that light consists of waves, produced in a medium called ether; which ether is not only present between the sun and the earth, but exists in every part of creation.

When a stone is thrown into water, you know waves are produced, which keep spreading further and further from the spot where the stone was thrown, until all the water in the pond becomes agitated: well, just as those waves are propagated in water, so is it imagined that others are in ether; and it is presumed that the violet light is produced by small waves, and the red light by large ones. It is impossible for me to tell you which of those two theories is correct; the question cannot be answered by much abler men than I am; but for my own part I greatly prefer the theory of waves.

Heat is said, by chemists, to be caused by a substance termed caloric; but what this caloric may be no one knows. A late opinion is, that when there occur in the ether, which I have just mentioned, waves larger than are necessary to produce red light, then those very large waves give rise to heat; this point, however, must be settled by more clever men than ourselves. We, if you please, will have a few words about the properties of heat, leaving out of the question that which produces it.

Now in order to learn a little about heat, let me suppose that you put a poker in the fire, and keep it there until it becomes red-hot. Just consider what you learn, even by this simple experiment. You learn that heat will pass from one body to another; because it has passed from the materials in the fire-place to the poker: this is called transference; you also learn that heat is capable of traversing, or of being conducted from one end of the poker to the other, this is termed conduction: you moreover learn that a great quantity of heat makes bodies luminous, inasmuch as the poker becomes red, and gives out light; chemists term this luminousness "*incandescence*." If you were to measure the poker when cold, and afterwards when hot, you would find that by heating, it increases very much in size, or, in scientific language, becomes expanded. If in place of a poker you were to employ a piece of stick, then instead of mere incandescence you would have an instance of combustion. It appears, then, that amongst the leading properties of heat, are a capability of being transferred and conducted, also of producing expansion, incandescence, and combustion.

Now I may explain to you the reason why the plate was supposed to break in the imaginary experiment of drying wet sand. You have just been informed that heat expands bodies, that is to say, makes them larger; now the outside of the plate, or that part in contact with the fire, was necessarily hotter than the inside, on which was placed the sand; consequently it was larger, or rather *strived to become larger*, and in doing so tore itself away by main force from the inner and cooler part: hence arose the crack. Whenever, then, you have occasion to heat brittle bodies do so gradually, in order that one part may not be *very hot* at the same time that another part is *very cool*, by this means you will be likely to prevent a fracture.

A pretty instance of the expansion of bodies by heat is seen in the inflation of a fire-balloon, which is a large oval bag of tissue-paper, having a wide neck, kept extended by means of a wire. In this neck is placed a piece of sponge soaked in spirit-of-wine. Now this balloon is caused to ascend by proceeding as follows: let two or three persons separate its sides, while another applies a light to the sponge. The spirit-of-wine when burning produces a large flame, which makes the air inside the balloon very hot, therefore this air expands or increases in size, and the balloon being incapable of holding the whole, a portion of it escapes, consequently the balloon is filled with air of extreme lightness, and therefore ascends.

A more useful application of the expansion of bodies by heat, is seen in the construction of the thermometer, which is an instrument for ascertaining how hot, or how cold any substance may be. Perhaps, you think that the quantity of heat or of cold may be ascertained by the sense of touch; but in this idea you are quite mistaken, as I shall presently demonstrate. I will suppose that you are placed with naked feet in a room which is but partially carpetted, and without a fire. Whilst standing on the carpet, your feet do not feel very cold; you step from the carpet upon the wooden floor, and feel much colder; you then place your feet upon the marble hearth and exclaim, bless me, how *very* cold! one step more brings your feet in contact with the fire-irons, when your very teeth chatter because the sensation of cold is intolerable.

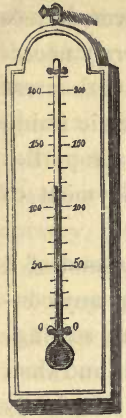
Now, if you were asked which was coldest, the carpet, the wood, the marble, or the fire-irons, you would think the question a very silly one, and without consideration you would immediately answer, oh! the fire-irons, to be sure. How much then will you be surprised when I affirm that they are all of the same temperature, and that your feelings have been in a manner telling untruths. If we light a fire in the grate, then what will be the consequence? why the carpet will feel cool, the wood warmer, the marble hearth hot, and the fire-irons,—O, touch them not! they would burn you. Perhaps you are aware, that the higher we ascend in the air the greater cold do we experience; hence it is that on the tops of high mountains there exists perpetual snow. Having remarked thus much, I will relate to you a tale. Once upon a time, as reports say, two travellers were engaged in exploring the celebrated Mont Blanc. One traveller having got half-way up met the other traveller, who had got half-way down: "Bless me, how cold!" said the ascending traveller: "Bless me, how hot!" said the descending one. Do you not understand the reason of these remarks? The ascending traveller kept losing heat, the descending one kept gaining heat, and this solves the whole mystery.

You see, then, that our feelings are not correct in their estimation of heat and cold: not only you but the poor travellers were mistaken; therefore, to prevent future mistakes, let us investigate the subject a little more narrowly.

We find that the sensations of heat and cold do not depend upon the actual quantity of heat possessed by any substance, but upon the difference existing between its temperature and the temperature of the hand or other part of the body which touches it; also upon the facility with which substances conduct or carry away heat. Now a woollen cloth, being a very bad conductor of heat, could not take away the heat of the feet, hence it seemed warm; and the fire-irons (like all metallic bodies) conducted or carried away the heat very fast, and hence they appeared cold. Just as woollen cloth will not carry away heat from you, neither will it convey heat to you; therefore it was that the celebrated Fire King always wrapped himself in flannel when he entered the hot oven. Unscientific people thought he did so to make himself hotter, but he very well knew that the flannel kept him very much cooler than he otherwise would have been.

Remember, then, that there exists nothing in the nature of flannel to render it hotter than wood, or stone, or iron; only it is a bad conductor of heat, and hence in common language is termed warm.

Well, then, if one is not to believe his own feelings, what *is* he to believe? Why there is a little instrument called a thermometer, which very prettily gives us all the information we require respecting the temperature of bodies. You remember my telling you that hot substances were larger than cold ones; on this very principle is constructed the thermometer. Thermometer tubes are filled with various substances, but I shall describe the mercurial thermometer. First, then, let me inform you that there exists a metal which, unlike every other, is a liquid at ordinary temperatures:—this metal I allude to is named quicksilver or mercury.



This plate represents a mercurial thermometer. You see it consists of a glass tube having a very small bore; one end of the tube has been blown into a bulb, which is full of mercury, and the other end is closed. Those marks which you observe with figures attached to them are called degrees. Now, on touching this bulb with my warm hand, the mercury rises in the tube, because the heat makes it so large that the mere bulb cannot contain it. The hotter the quicksilver is made, the larger does it become, and consequently the higher does it rise. The heat of my hand has caused the quicksilver to rise as far as ninety degrees; therefore I know that the temperature of my hand is equal to ninety degrees. Instead of mercury, some thermometers contain spirits of wine; but whatever the fluid may be, the principle of its action is the same. Now, about electricity, or the electric fluid, I shall say but little. Perhaps you have heard of the electrical machine, and I may tell you, that by means of this machine we are enabled to collect or force into a small space a great quantity of a very peculiar imponderable substance, termed electricity. Electrical machines are merely necessary when it is required to operate with great quantities of electricity, or the electric fluid; and I can give you some idea of the properties of this electricity without the employment of any machine at all.

First, tie a very light feather to the end of a piece of silk, and then suspend it from any convenient support. Now take a piece of sealing-wax, which briskly rub upon flannel, and then bring it into contact with the feather; the latter will appear to be endowed with life, and will approach the sealing-wax until both come into contact. After a short time the feather will leave the wax and fly back to its original position. Now the motion of the feather, which I have been describing, is occasioned by electricity.

If a piece of glass be substituted for a piece of sealing-wax, then will the glass also attract a feather or other light substance; but you will observe this curious fact, that when the feather is tired of remaining in contact with the electrified glass, then will it immediately go towards the sealing-wax; from which circumstance it is presumed that there are two kinds of electricity, one from glass, called vitreous, (*vitrum* being the Latin word for glass,) and another from resinous substances, like sealing-wax, called resinous.

The electrical machine is merely a contrivance for rubbing a large piece of glass by machinery, instead of giving one the trouble of doing so by the hand.

I must not forget to tell you that thunder and lightning depend upon electricity, nor must I omit to mention the means by which the celebrated Benjamin Franklin discovered this. Certain circumstances led him to believe that the phenomena of thunder and lightning depended upon electricity; and he reasoned thus:—Electricity will pass through metal, therefore I want a piece of metal which shall approach very near to a thunder-cloud and reach to the earth, when, if electricity be really contained in this thunder-cloud I shall bring it to the earth. But, thought he, how am I to raise my metal high enough? Thus reasoned the statesman and philosopher, Benjamin Franklin. Remark, now, how cleverly he accomplished his purpose: through a long piece of cord he ran a very fine wire, and providing himself also with a silk handkerchief and two pieces of lath, he went into the fields on the approach of a thunder-storm. When arrrived at his destination, he tied his sticks together across each other, and straining over them a silk handkerchief, he made a kite, to which he attached the string and flew it aloft. Very soon a thunder-cloud passed over it, and the philosopher placing his knuckle near the string, drew an electrical spark; thus proving that his suppositions relative to the nature of thunder and lightning were all correct.

By this circumstance you learn, that even the toys of boyhood may be converted into valuable instruments in the hands of a person who is really bent upon the study of philosophy. The experiment of Franklin is exceedingly dangerous, and one that I would not have you repeat, since a quantity of electricity might pass down the cord quite sufficient to destroy life; indeed, there have already been several instances of death occasioned by trifling with thunder-clouds. Electricity does not pass through all substances with equal facility—metals convey it with scarcely any interruption, hence they are called conductors; but glass, wax, resin, and silk, together with some other bodies, intercept nearly the whole of it, hence they are termed non-conductors.

Tapering above the church-steeple of this village is a pointed piece of iron, termed a lightning conductor; it passes down the side of the edifice deep into the ground, and its use is to protect the building against lightning. If the rod were not there, a thunder-cloud passing over the steeple might suddenly dart upon it an immense quantity of electricity, in the form of a flash of lightning, and shatter it to pieces; but the iron would prevent such an accident, by conveying the fluid silently, rapidly, and safely into the ground. Well, you will always remember that the imponderable substances, or those without weight, are

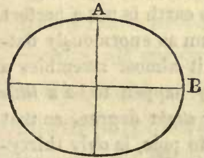
Light,
Heat,
Electricity.

The old philosopher, having finished his second Lecture, called us around him, and explained, that on the occasion of our meeting again, he would instruct us in the manner of performing chemical experiments, each one for himself. " *I*," said he, " will take *my* instruments, and you shall take your instruments; that which I do you will imitate, and in this manner each of my young friends will speedily become an expert chemist." But his descriptions were so intelligible, that even had he not shown us, we should have known what he meant. I hope, therefore, that all who read his Lectures, and see copies of his drawings and instruments, will be able to perform the necessary experiments without the personal assistance of the old philosopher.

LECTURE III.

EXPLANATION OF WHAT IS MEANT BY THE TERM *WEIGHT*—PONDERABLE BODIES, OR THOSE WHICH POSSESS *WEIGHT*—SPECIFIC GRAVITY.

Before I describe to you the nature of ponderable bodies, or those which have weight, it is necessary for me to explain what weight is. All substances within a certain distance of the earth (except light, heat, and electricity) are drawn towards the centre of the earth with a certain force, and the degree of force with which a body is so drawn or attracted is termed its weight. Now the further a body is removed from the centre of the earth the less is its weight; consequently, as the earth is somewhat of this shape,* a body at B will weigh less than a body at A; therefore the weight of a substance is less at the equator than at the poles. When a stone is thrown into



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* In order to make their remarks more impressive, lecturers are very often guilty of exaggeration, which is the case in

the air it falls again to the ground because of its weight. Little do you think that the whole earth is moved by the mere throwing of a stone; but such is indeed the case. The earth attracts the stone, and the stone the earth, therefore each moves towards the other; but as the stone is infinitely smaller and lighter than the earth, so does it move the earth to an equally small extent. A person when jumping or dancing moves the earth, however little he may be conscious of the fact. Perhaps then, in future years, when I shall be dead and gone, some of my young friends, whilst engaged in the merry dance, may call to mind what an old man once told them about their moving the world.

This force which causes bodies to approach each other is termed gravity or gravitation; sometimes also it is called the centripetal force,

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the present instance; for the old gentleman, wishing to make his audience remember that the earth is not a perfect globe, has represented it in his diagram so enormously flattened at either pole, that in shape it almost resembles a turnip. Now the earth *does* certainly happen to be a *little* flattened at each pole, yet in a very *slight* degree, so that the diameter of the earth, from pole to pole, is only thirty-five miles greater than its diameter at the equator. Although, then, the old gentleman has chosen to make the earth appear so enormously flattened in the diagram, yet the reader should remember that, strictly speaking, this is not correct.

because it makes bodies approach each other's centres. Gravitation, or the centripetal force, and the centrifugal force, acting conjointly, retain the planetary bodies in their orbits: if gravitation acted alone, then those planets would all come together. If the centrifugal force acted alone, then would they continually separate from each other; but both operating together, the planets are made to revolve round the sun as a centre. The power of gravitation, or the weight of bodies possessing equal sizes, is in proportion to their density. An orange is much less dense than a cannon-ball of equal dimensions, and therefore is much less heavy.

The sun is 137,763 times larger than the earth, but his density is only a little more than a fourth of the density of the earth; that is to say, if a piece were cut out of the sun equal to our globe in size, it would only be one-fourth and a little more of the earth's weight; and, of course, all substances on the surface of such a body would only weigh a little more than one-fourth part of what they do here. However, so immensely great is the size of the sun, that notwithstanding his diminished density, a moderate man would weigh on his surface no less than two tons, and consequently would not be able to move; whereas, if placed on the little planet Vesta, he would weigh only a few pounds, and might probably be blown away by the first puff of wind. If, then, you should be asked the meaning of gravity or gravitation, you would say that it was the force which attracted masses towards each other; and if you were asked the meaning of the term weight, you would say it was the estimation of the gravitating force of any body.

In philosophical books there frequently occurs the term specific weight or specific gravity. I will soon render the subject of specific gravities intelligible by means of a few examples.

Suppose I weigh any given measure of water, say a square-inch, and call its weight one, or unity; after having done this, suppose I weigh a square-inch of iron, and find its weight to be eight times greater than unity, or the weight of an equal bulk of water; of copper, and find its weight to be nine times greater; of lead, and discover that *its* weight is eleven times greater; I should say that the specific gravities of iron, copper, and lead were eight, nine, and eleven, respectively; water being one, or unity. Instead of taking water for unity, I might have chosen some other substance; but, upon the whole, water is most convenient as the unit of comparison for solids and liquids, and atmospheric air for gases. If, then, you should be told that the specific gravity of a liquid or solid is two, three, four, or, in short, any other number, remember that those numbers indicate how much heavier a substance is than an equal bulk of water. When, however, you hear or read of the specific gravity of a gas, remember that its weight is compared with an equal bulk of atmospheric air.

If we could measure out given quantities of any substance we pleased, and compare their weight with an equal quantity of water, the theory of ascertaining specific gravities would be very easy; but we are frequently obliged to obtain information in an indirect manner, inasmuch as it is not always possible to convert a body whose specific gravity is required into the proper size and shape. The method of taking specific gravities of solids and liquids I shall describe when speaking of water, and of gases when speaking of air.

I have already mentioned that the ancient Greeks and Romans imagined all substances in nature to be composed of four elements—fire, air, earth, and water. Now fire is not an element at all, being merely an effect of certain chemical changes; as to air and water, each is composed of two different gases, and earthy bodies are made up of the rusts of various metals. A chemist, speaking to persons acquainted with his science, would make use of the word oxide instead of rust, but I prefer employing the latter term because it is most easily comprehended. We speak of iron rusting, and of copper and lead tarnishing; well, this rust, or tarnish, is nothing more than an oxide of the several metals. Lime is the rust or oxide of a metal termed calcium, and magnesia the rust, or oxide, of the metal magnesium: now lime and magnesia are earths: the mould of gardens and fields, which, in common language, is termed earth, consists of the real chemical earths, mixed with different other substances, such as animal and vegetable matters undergoing decay.

Potash is the rust or oxide of a metal called potassium, and soda of the metal sodium. Potash and soda are termed by chemists alkalies. In short, there are forty-two metals, each of which is capable of crumbling into rust or oxide, either by natural or artificial means, and those oxides are possessed of various properties.

It appears, then, that the ancients knew very little of chemistry; and if they could now revisit the world and see the wonderful discoveries which have been made, they would be very much astonished indeed.

There are, I mentioned, fifty-five elements, or, as they are sometimes called, simple substances, besides the imponderables. If I were writing a large book on chemistry I should classify those substances, and tell you a good deal about each of them; but now I shall merely divide them into the metallic bodies, or those which are metals, and the non-metallic, or those which are not metals. The names of many in both of those classes you have never heard of, I shall therefore omit their description, and only mention such as are best known or most interesting. In my next Lecture I shall speak of the non-metallic simple bodies individually. They are,

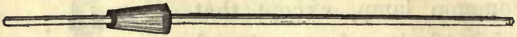
Oxygen,
Nitrogen,
Hydrogen,
Chlorine,
Iodine,
Bromine,
Fluorine,
Carbon,
Sulphur,
Selenium,
Phosphorus,
Boron,
Silicon.

LECTURE IV.

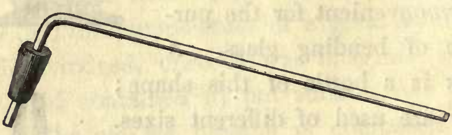
OXYGEN.

THE word oxygen is of Greek origin, and signifies the acid maker; so called, because it enters into the composition of a great number of acids; indeed, once it was imagined that every acid contained it, but such is not the case. The air we breathe is composed of twenty-one parts by measure of oxygen gas, and seventy-nine of another gas, called nitrogen; but oxygen gas is never procured from the air, the process being too troublesome. There are many ways of getting it, but I shall content myself with showing you that process which is easiest for you to follow, and which affords oxygen gas of the greatest purity. But the process requires some instruments, and I am going to show you how to make a great many of your own. First of all you must procure a spirit-lamp; a piece of small glass tube, or pipe, about the size and thickness of a goose-quill, and a glass flask. Now first let me describe to you the use of your tools, for you are going to work glass. A spirit-lamp is an instrument of this shape, and in no respect differs from a common lamp, except that spirit-of-wine is employed instead of oil. Spirit-lamps are much used by chemists as sources of heat, and are very convenient for the purpose of bending glass. A flask is a bottle of this shape; they are used of different sizes. Florence flasks, or those which come from Florence, in Italy, full of olive-oil, are much used in chemical experiments; but for your present purpose you do not require a flask which is more than an inch in diameter. It should be made of green glass; a substance which withstands the application of heat much better than that which is white.

Fit tightly into the mouth of your flask a very sound cork; now take it out, and by means of a red-hot wire make a hole through it exactly large enough to admit the end of the glass tube;* which being done, you will have formed an instrument of this shape—



however, you do not want it straight, but bent like this;



therefore you must now light your spirit-lamp, and applying the heat gradually to the tube, you will find that, after a short time, it bends as easily as a stick of warm sealing-wax. Now cool it gradually, and you are prepared to commence the operation of making oxygen gas. Into your flask place about half a drachm of the substance called chlorate of potash, and then insert the bent tube with the cork attached; you will have an instrument, or apparatus similar to this diagram.*

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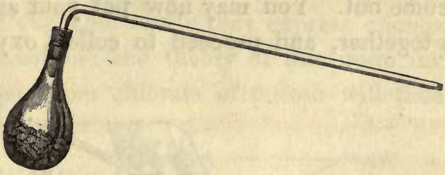
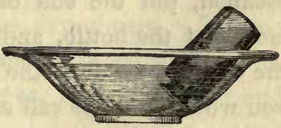
* Corks may be most easily perforated by pressing against them, with a rotatory motion, a piece of brass tube filed to a sharp edge.



Now chlorate of potash is a substance that contains a great quantity of oxygen in a solid form; and by the application of heat it gives off the whole of this oxygen in a gaseous state; consequently, if you make your flask very hot by means of a spirit-lamp, oxygen gas comes over: but how must we collect it? you will say: I will tell you. Take a basin of water and put into it a small bottle, so that the latter may also become filled with water; then invert the bottle in such a manner that its mouth may still continue under water, and you will have an apparatus of this form. So long as the mouth of the bottle remains under the



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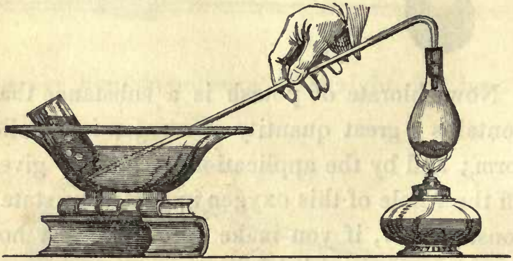
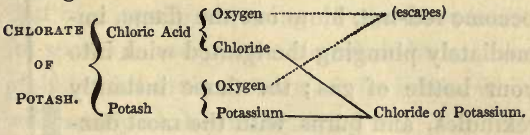
* If the flask be small, and not overcharged with ingredients, its separation from the tube will be amply guarded against by the mere pressure of the cork; if larger and more heavy, it may be secured by means of a little thread.

surface of the water in the basin that portion of water which the bottle itself contains will not come out. You may now put your apparatus together, and proceed to collect oxygen gas.



Very soon after the application of heat, the chlorate of potash melts; then boils, and the gas which comes over rises through the water. You must not collect the first few bubbles, for they are contaminated with the air which filled the flask and tube; when those bubbles have escaped, put the end of the tube under the mouth of the bottle, and gas ascending drives the water out, until the bottle becomes what you would perhaps call empty, but it is full of gas. I shall not now stop to describe the changes which have taken place in preparing this gas; however, I will give you a diagram, which had better be copied into your notebooks. On some future occasion I will explain the nature of *chemical* diagrams, and show you how easily they express changes of composition: the theory of the production of oxygen from chlorate of potash will then be intelligible.*



I now mean to teach you the properties of this oxygen gas, and you will require many bottles of it: as soon as one is full take it away, substituting another in its place. When you observe that all the water is driven out from a bottle, proceed as follows:—Take a small square piece of window-glass, grease it well on one side, and place the greased side under water against the mouth of the bottle, which may be now taken out and put upon a table.

Suppose we have an experiment. To one end of a piece of copper wire affix about an inch of small wax taper, pass the other end first through a perforated disc of tin-plate, just large enough to cover the mouth of the bottle, and then into a cork which serves as a handle. Afterwards bend the wire to this shape. Now light the taper, and when the wick has become red-hot, blow out the flame, immediately plunging the ignited wick into your bottle of gas; the flame instantly rekindles, and burns with the most dazzling brilliancy. Particularly remember, that although oxygen gas makes other substances burn so very well, still it is quite incapable of burning itself, therefore, in chemical language, it is said to be a supporter of combustion, but a non-combustible.

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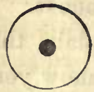
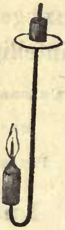
* On the large scale, oxygen gas is procured from a substance called the per-oxide of manganese, either by heating it in an iron retort, or by applying heat to this substance, mixed with oil-of-vitriol, and placed in a retort of glass.





Now place another bottle full of gas on the table, for I intend showing you a still more wonderful experiment,—the burning of iron wire. Twist some small iron or steel wire, (a piece of steel piano-string is very good for the purpose) around a stick, by which means you make a coil something like a cork-screw. Now straighten each end of this coil; prepare one end with the disc and cork, as in the last experiment. To the other end attach, by means of some still finer wire, (either brass or iron,) the point of a brimstone match.

Now if you light this point, and then plunge the whole wire into one of your bottles full of oxygen gas, you will be surprised to see the wire burn with a brilliancy far greater than that of a candle, throwing off the most beautiful sparks in every direction, while little melted globules fall to the bottom of the bottle, which will most probably break.

I wish you particularly to remember one thing in connexion with the experiment just performed: the globules of melted metal, which fall during the process of burning, are found, when weighed, to be *much heavier than the iron from which they are produced;* proving that the iron during combustion unites with something which has weight; now this something is oxygen, which, losing its gaseous state, becomes solid. I have already told you that rust of iron is nothing more than iron combined with oxygen: well, besides this red oxide of iron, there is another, which when prepared by certain methods is black; the melted globules which our experiment has produced, are masses of black oxide of iron.

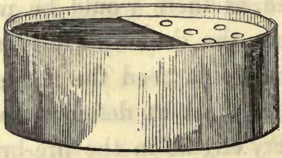
There are many other experiments which you might perform with oxygen gas, but some of them are very dangerous, and therefore I omit to mention them until all of you become more clever at chemical *manipulation.* This word means a handling, and has reference to the dexterity with which you use your instruments.

If you were to put a mouse into a large bottle full of oxygen gas, the poor little animal would jump about as if it were mad; not from pain but from delight, because the breathing of oxygen gas produces a kind of intoxication, or, to speak more correctly, acts as an excitant to the nervous system. Well, you may now form some idea of the general properties of oxygen gas, and I just wish you to remark what would be the consequence if we were to be surrounded with this gas instead of air.

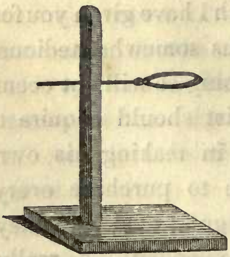
In the first place, then, all living creatures would be somewhat in the poor mouse's condition; men, beasts, and birds, would all run wild together. The fishes too might grow insane, so far as I know, for I shall by and bye tell you that fishes breathe as well as ourselves.

Again, every thing in nature would burn as soon as it acquired a red, or at most a white heat. We could not make the poker very hot but it would burn; we could only extinguish a candle by cutting off the wick; and if a house should be on fire the consequences must be awful indeed, as there would be no means of extinguishing the devouring element, the terrific oxygen would feed the flames on every side, and would set at defiance the united efforts of every engine in the fire-brigade. Indeed, the whole world must shortly be in one general conflagration, and it has been imagined, (not without some shade of probability,) that the earth may be consumed in this very manner at the last day. The atmosphere consists of oxygen and nitrogen; consequently if the Divine Author of nature were to take away the latter, and to leave the former alone remaining, the whole earth must be inevitably consumed.

I fear, my dear young friends, you will consider the long directions which I have given you for making your own apparatus somewhat tedious, but the necessity for my doing so will not occur very often. Every chemist should acquire a certain kind of dexterity in making his own instruments; if you were to purchase every thing you might require, a great deal of money would be unnecessarily expended. A really scientific man will manage to perform his experiments with such instruments as may lie within his reach. There are sold in the shops instruments called pneumatic-troughs, which



are troughs supplied with perforated shelves, over the holes of which you may stand inverted bottles full of water; but a basin or finger-glass answers very well for all common purposes; and if you wish to supply it with a shelf, your own ingenuity will soon enable you to make one. Again, instead of holding your flask all the time the process is going on, mere convenience would soon induce you to invent some kind of mechanical support to answer the



same purpose. A piece of stout wire with a ring at its extremity, capable of being fixed at different heights, in an upright stick, is a very good contrivance; but if you wish to perform your experiments before an audience, and to make a grand display, then you may purchase chemical stands very neatly constructed at philosophical instrument makers.

It is the oxygen gas of the atmosphere which enables fires to burn and animals to live: from this latter property it is termed vital air. I shall not now speak of the process termed respiration or breathing, for before I do so it is necessary that you should be made acquainted with two other elements; that is to say, nitrogen and carbon: however, I may just arrest your attention by remarking that air several times breathed is converted into a deadly poison, which is neither capable of supporting animal life nor of enabling substances to burn.

Although we can only obtain oxygen in the form of gas, yet in combination it may be either a solid or a liquid. Rust of iron is merely a compound of that metal with oxygen, and oxygen exists as a liquid in both water and aquafortis. The immense importance of oxygen in the economy of nature may be learned from the fact, that at least three-fourths of the whole world, including its inhabitants, are composed of it; yet so wonderfully has the Creator united it with other elements, that all these fierce and intractable properties which it exhibits in an uncombined state, are lost by combination.

The experiments which we witnessed in the last Lecture so pleased us, that I, as well as many of my friends, repeated them at our own homes. We now felt convinced that the truths of chemistry were not difficult to understand, neither were chemical experiments difficult to perform. The glittering array of instruments in the chemists' and opticians' shops, had caused us to regard chemistry as something far beyond our understanding, and we had certainly no idea that so many instruments could be made by ourselves. The old gentleman having left much to our ingenuity, we followed up his suggestion, and tried to make oxygen by means still more simple than the flask, and tube, and basin. One boy, who was more expert than the rest, took a piece of glass tube, about six inches long, and having closed one end by means of a spirit-lamp, he put into the tube a little chlorate of potash; then he applied heat, and not only developed oxygen, but succeeded in burning a little coil of iron wire in the same tube, without using any other instrument whatsoever.

When the next lecture-night arrived, we found that our instructor had made an increase to his stock of apparatus:—there was on the table a glass receiver for gas, also a pneumatic-trough; those he informed us were very convenient; but, if necessary, he could do without them. "A wide mouthed bottle," said he, "would answer the purpose of a receiver, and a washhand-basin, of a pneumatic-trough."

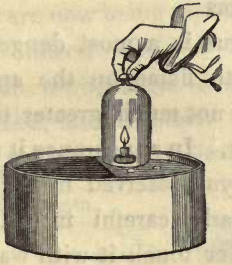
LECTURE V.

NITROGEN—HYDROGEN.

THE next elementary substance which I shall describe to you is nitrogen, meaning the former of nitre—also called azote, or the life-destroyer.

Nitrogen, like oxygen, may exist in the gaseous, liquid, or solid form, when combined with other substances, but it can only be procured in a separate state as a gas.

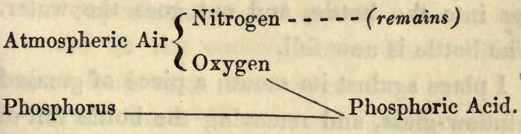
The air which we breathe consists of nitrogen and oxygen gases mixed together in proportions which never vary; every hundred parts of the atmosphere, by measure, is formed of twenty-one of oxygen and seventy-nine of nitrogen. I have already told you what would occur if our atmosphere had been pure oxygen, instead of a mixture of oxygen and nitrogen. Nitrogen, as a constituent of the atmosphere, may be compared to water in a glass of grog. You may smile at my illustration, but, I assure you, it is not a bad one. Nitrogen neither supports combustion, nor enables animals to live. Oxygen would soon drive us all wild, and set the world in a blaze. Nitrogen, therefore, is made to form a constituent of the atmosphere, in order to temper down, or dilute the excessive strength of the oxygen. I now fix a little piece of taper upon a large bung, in this manner, and having lighted the taper, I float the bung upon the water, which stands above the shelf of a pneumatic-trough. Over the taper I place a receiver full of atmospheric air.



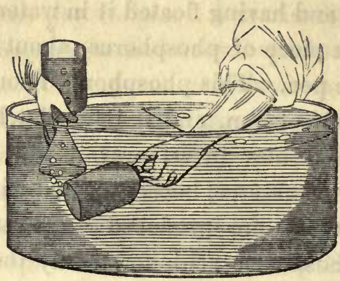
The candle, you see, burns at first well enough; now the flame becomes more dim; and now is extinguished altogether. It has taken away from the air in the receiver the greater portion of its oxygen, and therefore cannot burn any longer. I am leading you, then, by degrees, to understand the true theory of obtaining nitrogen. Although a lighted candle will separate the greater part of the oxygen existing in a given quantity of air, yet its flame is not sufficiently powerful to remove the whole; there is, however, a substance called phosphorus, which burns with such excessive vehemence, that by its combustion every particle of oxygen is removed. If I perform the experiment again, using a little phosphorus instead of the candle, every trace of oxygen will be removed, and nitrogen will be the only remaining gas.

Phosphorus is a most dangerous substance, bursting into flame on the application of a temperature not much greater than that of the human body. In appearance it resembles wax, and is always preserved in a vessel of water. Be particularly careful in using this phosphorus; never touch it with warm hands, and if you have occasion to cut it, always do so under water. After these remarks, you must be very clumsy indeed if you meet with any accident from phosphorus in preparing nitrogen gas.

I now take a little tin dish, such as tarts are made in, and having floated it in water, I place upon it a piece of phosphorus, about the size of a large pea. This phosphorus I touch with a piece of hot iron, and it immediately begins to burn. I now invert over it the receiver, which, you observe, becomes filled with white fumes: these are produced by a substance called phosphoric acid, formed by the combination of phosphorus with oxygen. The phosphorus has now ceased burning, and water, you observe has risen in the receiver, proving that *something* has been removed, which something is oxygen gas. The white clouds of phosphoric acid are now being rapidly absorbed by the water; indeed while I speak they are gone, and pure nitrogen gas alone remains; colourless, tasteless, and invisible.



Let us now proceed to transfer our nitrogen into bottles, that we may try some experiments with it. As the mouths of our bottles are so much smaller than the mouth of the receiver, we will use a funnel for the purpose of transferring the gas with greater ease.



I would advise you all to turn up your wristbands and coat-sleeves, for your arms must be immersed a little under water.

You see, I put the bottle under the surface of the water, so that it may become full. Beneath its mouth I now place a funnel; and underneath the funnel I gradually invert the receiver. Bubble, bubble, bubble—up goes the gas into the bottle, and out goes the water. The bottle is now full.

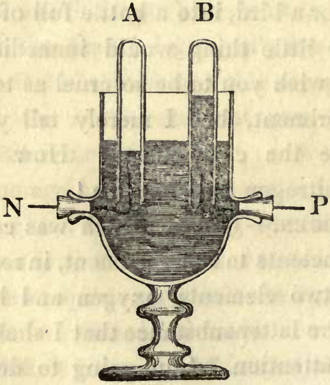
I place against its mouth a piece of greased window-glass, and removing the bottle full of gas, I put it to stand on the table. We shall each of us require two bottles full of this gas, therefore I transfer some more.

Now take a bent wire and taper, such as you used for an experiment with oxygen; and having lighted the wick, plunge it into one of the bottles of nitrogen. Mark what takes place—the flame is immediately extinguished.

Into another bottle let us throw some lime-water, and covering over the mouth, we will shake it violently. You are expecting to see some change; but there will not be any. I wished you to perform the experiment for the following reason. Nitrogen is very similar, in many of its properties, to another gas called carbonic acid. *Carbonic acid*, however, *whitens lime-water*, although nitrogen does not, and by this means one may immediately distinguish them.

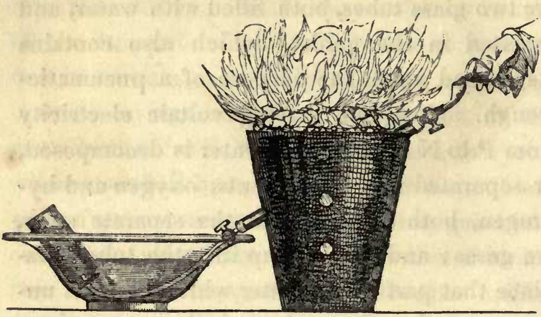
If you were to put a small animal, such as a mouse or a bird, into a bottle full of nitrogen, the poor little thing would immediately die. I do not wish you to be so cruel as to perform the experiment, but I merely tell you what would be the consequence. How different, then, is nitrogen from oxygen!

HYDROGEN.—Water, which was considered by the ancients to be an element, in reality consists of two elements, oxygen and hydrogen. It is to the latter substance that I shall now direct our attention. I am going to describe to you a method of proving that water actually consists of two gases. There is an instrument called the galvanic or voltaic battery, much used for the purpose of generating electricity of a peculiar kind Electricity, you know, is one of the imponderables, or substances without weight, a substance which I have purposely omitted saying much about, inasmuch as its consideration will be better adapted for you, when you shall have become more acquainted with chemical science. Well, then, galvanic, or voltaic, electricity separates water into its two elements, oxygen and hydrogen. The way to proceed I shall now explain to you, by means of a diagram. An instrument is required of this shape.



It consists of a glass goblet, perforated on either side; in which perforations are fixed corks, and through these corks are passed wires, communicating with a galvanic battery. A B are two glass tubes, both filled with water, and inverted in the goblet, which also contains water, and serves the purpose of a pneumatic-trough. Now, on passing voltaic electricity from P to N a portion of water is decomposed, or separated into its elements, oxygen and hydrogen, both of which, in the separate state, are gases; and passing up into the tubes, displace that part of the water which remains undecomposed. One tube contains oxygen gas, and the other tube hydrogen gas. It is found, moreover, that the quantity of hydrogen produced in this manner is twice as much by measure as the quantity of oxygen. Consider attentively the description I have given to you, and always remember that water can be proved to consist of oxygen and hydrogen, in the form of a liquid. The plan is far too inconvenient for general employment, and I only mention it in order that you may be convinced it is possible to separate the two elements of water, and to obtain each unmixed with the other.

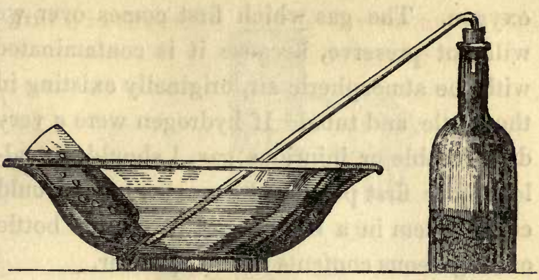
I can tell you another way of proving the composition of water, although not exactly so satisfactory as the one just mentioned. If we make a gun-barrel red-hot, by means of a little chemical furnace, thus,



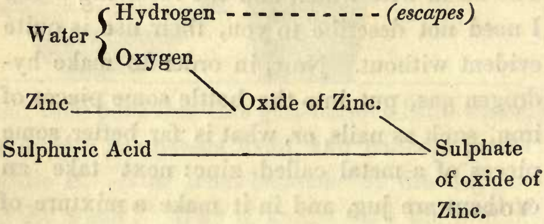
and then pour into this gun-barrel a little water, hydrogen gas passes over, and collects in the bottle B. Now what becomes of the oxygen of the water? Why it unites with the iron of the red-hot gun-barrel, and forms the solid oxide of iron.

This also is an experiment which I merely wish you to remember, and not to perform; for I made a promise, that in the early part of your study there should not be employed any charcoal furnaces, or bellows;—no soiling of the hands, hard work, or burning of clothes.

I shall now show you the process of making hydrogen with the greatest ease. Take a pint wine bottle, and adapt to its mouth a cork and bent tube, in this manner.

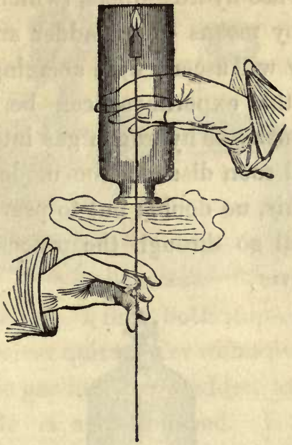


The basin with water, and the receiving bottle I need not describe to you, their use is quite evident without. Now, in order to make hydrogen gas, put into the bottle some pieces of iron, such as nails, or, what is far better, some pieces of a metal called zinc: next take an earthenware jug, and in it make a mixture of one part, by measure, of sulphuric acid, or oil of vitriol, and ten parts of water. The process of mixing those substances develops a great quantity of heat, hence, if you were to add one to the other in the bottle, instead of the jug, the glass would immediately break. Pour this mixture over the zinc until the bottle becomes about a quarter full; then immediately replace the cork, and you observe that hydrogen gas passes through the tube in great abundance: it may be collected in a manner precisely similar to oxygen. The gas which first comes over we will not preserve, because it is contaminated with the atmospheric air, originally existing in the bottle and tube. If hydrogen were a very disagreeable or injurious gas, I should not allow those first portions to escape, but I would collect them in a bottle, and empty the bottle of its gaseous contents in the open air.



As we have now obtained several bottles full of this gas, let us place them in order upon a table, and I will show you how to perform some very pretty experiments

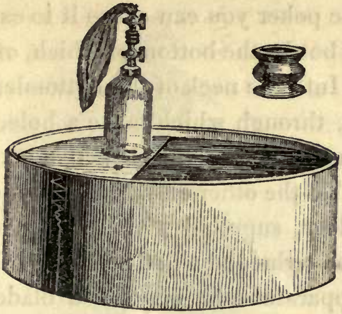
In your left hand take up a bottle full of the gas, then let an assistant put his hand on the glass plate. Now invert the bottle, and let the glass plate be gently removed with a sliding motion. This being done, raise into it a lighted taper, fixed on the end of a wire.



You see what occurs;—the gas itself burns at the mouth of the bottle with a pale blue flame, but the taper is extinguished. By this experiment you learn that hydrogen gas is a very good combustible, but yet is incapable of supporting the combustion of another body, which I need scarcely remind you is quite the reverse of oxygen.

Hydrogen gas is the lightest of all ponderable substances; this extreme levity we can prove by a very simple experiment. All of you, I dare say, have blown soap-bubbles, by means of a tobacco-pipe. If, instead of the breath, we use hydrogen gas, (which can easily be done by means of a bladder and tobacco-pipe,) they will ascend with amazing velocity.

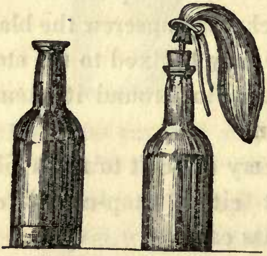
Before this experiment can be performed, we must put some hydrogen gas into a bladder. You would soon discover the mode of accomplishing this, no doubt; but to prevent all mistakes I will go through the process. Take a glass receiver, supplied with a brass cap and stop-cock; also get a bladder, into the neck of which is firmly tied another stop-cock. By simply turning the stop-cock, the receiver, when placed upon water, may be made a close or open vessel at pleasure. I close it, then, and proceed to fill it with gas, just as I would a common bottle. I now dip the bladder in water, to render it pliable; squeeze out all the air which it contains, and by means of a connecting screw I join it to the receiver.



Having done this, I turn both stop-cocks, and press the receiver quite under water; which you see forces the gas into the bladder, and what I wished to do is accomplished. I now turn both stop-cocks, and unscrew the bladder. The tobacco-pipe may be fixed to the stop-cock, by winding a little cloth round its stem, and then screwing it in.

It is not very difficult to fill a bladder with gas, without either stop-cocks, connecting-screw, or brass cap.

Take a quart wine-bottle, and by means of a very sharp file cut a notch all round it, about an inch from the bottom. Now heat a poker red-hot, and apply it to the notch; most likely the glass will crack—it certainly will do so if you touch the hot part with a wet rag. When the crack is once made, by a cautious application of the poker you can cause it to extend all round the bottle, the bottom of which, of course, falls off. Into the neck of the bottomless bottle fit a cork, through which make a hole, and insert a glass tube, or indeed even a goose-quill will do. To the other end of the tube, or quill, tie a bladder, supplied with a string round its neck, to be tightened when necessary. By this simple apparatus one may fill a bladder with gas very well; but as gas-receivers and stopcocks are not exceedingly expensive, you see I have provided you with some.

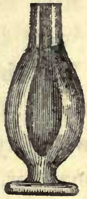


Well, the bladder is full of hydrogen gas, and I now proceed to blow some bubbles, by dipping the bowl in soap-suds, then taking it out, and squeezing it under my arm. You see how rapidly they ascend, proving that hydrogen gas is much lighter than atmospheric air.

At the philosophical instrument-makers are sold little balloons, which, on being inflated with hydrogen gas, ascend in a very pretty manner. The large balloons which ascend so frequently in London, and elsewhere, are not usually filled with hydrogen gas, although it is the most proper, but with coal-gas, named carburetted hydrogen, because it can be procured in such large quantities at much less expense.

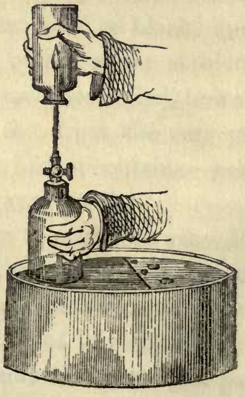
Hydrogen gas will not support animal life, yet it does not seem to be positively injurious, but merely kills by excluding oxygen. It would not do at all, then, for the atmosphere.

Hydrogen gas *burns*, but *does not support combustion*. Oxygen gas *supports combustion*, but *does not burn*. What then would you expect to be the properties of a mixture of these two gases? Why, clearly, that they would, when inflamed, give rise to the most rapid combustion possible, or, in other words, to an explosion: they do indeed explode with excessive violence, and when mixed in the proportion of two parts, by measure, of hydrogen, to one part, by measure, of oxygen, the sole result of the explosion is water. In philosophical instrument shops are sold very thick bottles of this shape, for the purpose of exploding mixed gases. In place of which may be employed a soda-water bottle: but the safest plan is to blow soap-bubbles with the mixed gas, from a bladder, and either ignite them as they ascend, or while they are still on the surface of the water.



This oxy-hydrogen gas can be burned by a peculiar mechanical contrivance, which I shall by and bye mention, with perfect safety, and the flame produces the most violent heat known; a heat that is capable of melting, and even burning the most refractory substances. Every five parts, by measure, of atmospheric air contain one of oxygen gas; therefore two parts, by measure, of hydrogen with one of atmospheric air also form an explosive mixture.

When hydrogen gas is burned, water is the only product of its combustion. This we may very easily prove. I take a jet-pipe, or what answers just as well, the stem of a tobacco-pipe, round which I wind a little cloth, and then attach it to the stop-cock of the glass receiver, filled with hydrogen gas, and standing over a pneumatic-trough. Having turned the stop-cock, I depress the receiver, and apply a light to the flame which issues: it burns, you see, with a very faint light, although its flame gives out a good deal of heat. Over the flame I invert a dry bottle, and see how a dew deposits on its sides. This dew is water which has been formed by the combustion of hydrogen.



The gas, then, is not destroyed by burning; it merely changes its form, by combining with the oxygen of the air. And here let me remind you, that no element on the face of the earth is ever destroyed. Even the process of combustion, associated as it is from our infancy with ideas of loss and destruction, merely causes bodies to assume new forms. All the fires ever kindled on the face of the earth, since its first creation, cannot have made it weigh one grain less than when, with verdure all beautiful, and with beings all happy, it was first rolled forth into space by the hands of its Creator.

LECTURE VI.

CHLORINE.

To-day I am going to teach you the mode of preparation, and the properties of another simple substance, termed chlorine, from its colour, *chloros* being the Greek word for green.

In a future Lecture I shall describe the metal manganese, or manganesum. At present, I need merely remark, that this metal unites with oxygen in various proportions, forming several rusts, or oxides: one is black, and hence is usually known by the name of black oxide of manganese; sometimes called, however, peroxide of manganese, from the very great quantity of oxygen which it contains—*per* being the Latin word for very much.

Well, in order to make chlorine, I mix together, in a Wedgwood-mortar, equal parts of peroxide of manganese and common salt. About two ounces of this mixture I put into a retort. I also mix in a jug equal parts of oil-of-vitriol and water, stirring them well together with a glass rod.

Before proceeding one step further, remark with what scrupulous attention I arrange the receiving bottles on the shelf of the pneumatic-trough. Here you see I have a bottle, capable of holding a quart, with its well-greased glass cover lying so near that it may be seized on the instant. By the side of this bottle are several others, each capable of holding a pint, and their greased glass covers are lying in order before me. The reason of all this order and precision I will very soon explain to you. In preparing gases, the first portions which come over should never be preserved, because they are always mixed with air. When the gas is harmless, like oxygen, or when not injurious in a diluted state, like hydrogen, then it may be allowed to escape into the air; but chlorine is exceedingly irritating to the lungs, even if breathed in a very small quantity. This large bottle, then, is for the purpose of collecting those impure portions, in order that none may escape into the air.

Well, you see I have put about two ounces of the mixture of salt and black oxide of manganese into a half-pint retort, and I now pour upon it enough of the sulphuric acid and water to make it into a thin paste. Observe, I shake the retort every now and then, in order that the whole of the powder may become moist, otherwise on applying the necessary degree of heat, the retort would certainly be fractured.

Some of my young friends are coughing, I hear, which proves that chlorine is already coming over, even before the application of heat. I now place the beak of the retort under the large bottle, and very gradually apply heat, by means of a spirit-lamp. Always apply heat to glass instruments very gradually, or else they break. The gas bubbles through the water in the bottle: now it is nearly pure, as I can perceive by its colour. My quart bottle is half full, and sliding it aside, I replace it by a pint bottle. This has filled, and I supply its place with another, and another, securing each with a well-greased glass plate immediately it is full.

We shall want chlorine for a future experiment, therefore let us put aside some bottles full of it. When you wish to keep gas in bottles, do not employ flat glass covers, but actual stoppers, well smeared with pomatum, and not only grease *them*, but also the interior of the bottles' necks.

After chlorine has passed over for some time, its supply begins to cease; and notwithstanding the application of heat no more gas is evolved: when this takes place, the retort should immediately be removed, or else some water from the trough will pass back upon the hot materials, and cause a fracture of the instrument. The retort is to be removed by wrapping a piece of cloth round its neck, and carrying it carefully away: take care that no water trickles from its wet neck upon its hot body—this too would cause a fracture.

In books you will read that chlorine must be collected over warm water, because cold water absorbs it: it is very true that water *does* absorb *some* chlorine, but this is of very little consequence, as the gas comes over in abundance, and when the water has absorbed a certain quantity, the objection is at an end. In practice I have always found cold water to be more convenient than hot, and therefore I recommend it to you.

I have made and collected *my* chlorine; now, perhaps, you will do the same, but as our stock of retorts is not very large, some of you must employ Florence flasks and bent tubes, which apparatus, indeed, answers just as well as a retort.

I have now lying before me several bottles full of this gas, with which let us try a few experiments.

It will be necessary for me to lower down into those bottles different wires, for the purpose of immersing a lighted taper, as well as some other matters. In addition to the tin discs, which we have hitherto used, I also employ others, made of card-paper and well greased; those I put under the tin ones, in order to prevent the escape of any chlorine from the bottles.

Into one bottle of chlorine I lower a lighted taper, which is immediately extinguished: chlorine, then, is not a supporter of combustion, you say: stop a little, and witness the next experiment before you make your decision. Into another bottle full of chlorine I lower a sheet of gold-leaf by means of a wire of this shape; see how vividly it burns. Chlorine then does support the combustion of gold, although not of a taper. Not only does gold burn when thus treated; for powdered antimony or powdered arsenic, both of which are

metals, burn when put into chlorine. Phosphorus also burns when similarly treated, and, indeed, a great number of substances besides; but I shall not show you those experiments, for when the metal arsenic is burned in chlorine, a chloride of arsenic results, which is a most dangerous substance if breathed; and the chlorides of antimony and of phosphorus are scarcely more innocent.

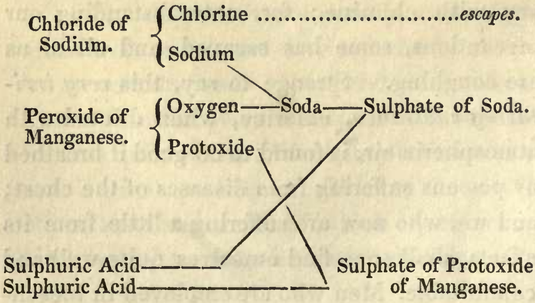
Chlorine is a great bleaching agent, and is used in great quantity for the purpose of whitening linen. The process of bleaching was formerly conducted by exposing dark cloths to the action of air and moisture: when this plan was followed, many months were required to complete the operation; now, by employing chlorine, a piece of linen may be bleached in the space of a few hours. Let us try this bleaching property of chlorine. Into a bottle full of it I drop a sprig of parsley, made slighty moist with water, and covering the bottle over let us wait the result: the parsley has already lost its beautiful green colour, and will very soon become quite white. Water may be made to absorb a great quantity of chlorine, the peculiar odour, taste, and smell of which it acquires. If it be desired to make a solution of this gas, we should employ distilled water, because of its purity, and all its atmospheric air having been expelled by boiling, of course, it has greater capacity for other gases.

Chlorine, whether alone or in soluble combinations, may be discovered by solutions containing silver.

To a solution of chlorine in water I now add a solution of nitrate of oxide of silver; (the lunar caustic of surgons;) immediately, you observe, there falls down a white, curdy matter, which is chlorine, in combination with the metal silver, called *chloride of silver*. But silver forms a white compound with many other substances besides chlorine; however chloride of silver cannot be dissolved in boiling nitric acid, although it immediately dissolves in hartshorn, this being the distinctive characteristic.

Those are all the experiments I shall show you with chlorine; for, notwithstanding our precautions, some has escaped, and all of us are coughing. Strange to say, this *very irritating substance*, chlorine, when diluted with atmospheric air, is found to do good if breathed by persons suffering from diseases of the chest; and we, who now are suffering a little from its effects, shall soon find ourselves quite well and comfortable. Men who are employed in bleaching manufactories, and who are obliged to inhale chlorine day after day, suffer very little inconvenience from doing so, and are said to be scarcely ever afflicted with that terrible malady, consumption.

I have not yet told you the theory of making chlorine, although each of you has gone through the process. To describe verbally the exact changes which take place in a chemical operation is often a tedious affair, and to such young chemists as those around me, the information, after all, would not be exceedingly valuable. Common salt is composed of chlorine united to sodium, and is therefore called chloride of sodium: it is the salt then which furnishes chlorine. Those of my friends who wish to investigate the matter more deeply, and to become profound chemists all at once, may examine this diagram.


Chloride of Sodium.
Chlorine ....escapes.
Sodium
Peroxide of Manganese.
Oxygen——Soda——Sulphate of Soda.
Protoxide
Sulphuric Acid——
Sulphuric Acid——
Sulphate of Protoxide of Manganese.

Before concluding this Lecture, I wish to mention three other simple substances, iodine, bronine, and fluorine, which in some respects resemble chlorine.

Iodine is a substance which, in appearance, very much resembles black-lead, or plumbago; its odour is somewhat like that of chlorine. When heated, it yields a vapour of a beautiful violet colour, from which circumstance it derives its name *'ioeides,* being the Greek term for violet.

I now put a little iodine into a flask, and apply the flame of a spirit-lamp; see what a beautiful violet-coloured vapour immediately arises.

Iodine and starch are very delicate tests one for the other. Here is some solution of starch made with hot water, but which has now become cold; to this I add a little fragment of iodine, and stir them well together; see what a deep blue colour the mixture has acquired. If then I wished to ascertain whether or not a mixture contained iodine, I should add a cold solution of starch, which, if iodine were really present, would certainly be coloured blue.

Iodine is procured from sea-weeds, but I shall not tell you the process, as the information would do you but little good, and you would, perhaps, think me a tiresome old man for my pains.

Bromine is an elementary substance which is procured from sea-water, and in many points of view resembles chlorine and iodine. Bromine is a liquid of a deep red colour, and possessing a very fœtid, disagreeable smell; from which property it derives its name, *bromos* being the Greek word for fœtid.

The test for bromine is also starch, which it does not colour blue, like iodine, but yellow or orange.

Fluorine is a substance which is procured from fluor, or Derbyshire spar: it has only been obtained within the last few years, and for my part, I have never seen it. Fluorine is represented to be a substance which dissolves nearly every thing it touches, and which in its general relations is similar to chlorine and bromine.

LECTURE VII.

CARBON.

THE next elementary or simple substance I shall speak to you about is carbon. I have already prepared you to expect that chemistry will reveal to you many wonders. I have already shown you that the simple substance, oxygen, may be at one time a gas, at another a liquid, and at another a solid; but now I am going to tell you something still more extraordinary. Charcoal and the diamond are, chemically speaking, the same substance: charcoal can be procured from spirits-of-wine, from rum, or brandy. Charcoal may exist as one ingredient entering into the composition of an invisible gas, which gas may be got from limestone, or from the bubbling soda-water and sparkling champagne.* Oh! I might mention many other extraordinary things about this substance, but let me explain what I mean by asserting that charcoal and the diamond are, chemically speaking, the same. You already know enough of chemistry to be aware that the appearance of a substance is no indication of its composition. All bodies are believed to be made up of little parts or atoms, so small that they cannot be seen even by the most powerful magnifying glasses; but which are, nevertheless, upon very strong grounds, supposed to exist. The reason of this supposition I shall not now inform you; but when you have made a little further advancement in your chemical studies I will. For the present, then, remember, we have every reason to suppose that bodies are made up of little particles or atoms, and the theory relative to those atoms is termed the *atomic theory.*

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* "In order to give some idea of the proportion in which carbon exists in different common substances, it may be observed, that a pound of charcoal is equal to, and contained

Now, supposing charcoal and the diamond both to be made up of similar atoms, it is easy for one to imagine, that in charcoal those atoms

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in rather more than two pounds of sugar or flour, and of eight of potatoes or limestone; so that a mountain of limestone contains the essential element of, at least, an equal bulk of potatoes, and of a forest that would amply cover many such mountains."—*Prout's Bridgwater Treatise on Chemistry, Meteorology, and the Function of Digestion,* p. 117.

may be differently arranged to what they are in the diamond, and that consequently one substance is beautifully bright and transparent, whereas the other is black, dull, and dirty.

From this, as well as from many other facts, you will find that chemistry is well adapted to impress on your minds the truth which you have so often heard inculcated, that things must not always be judged of by appearance. It would be profitable for those who are vain of jewellery to remember, that the sparkling diamonds which bedeck their persons, dug, as they have been from the earth, by the labour of ill-treated slaves, bought at an enormous expense, and polished with the greatest care, are still but little removed from so many lumps of charcoal, than which, although more elegant, they are far less useful.

The most common way of making charcoal is to place sticks in pits dug in the earth, then to set those sticks on fire, and afterwards to cover them up with turf, by which process they are slowly burned, and charcoal remains. To perform this burning cleverly requires much experience, trouble, and attention. Some persons are so expert that they can convert an ear of corn into charcoal, without destroying the form of the grain; or having carved the resemblance of an arrow, feather and all, out of wood, they will not during the operation destroy the part representing the feather.

The best charcoal, however, is made in another manner, by putting billets of wood into a large iron retort, which is then made red-hot; by this process very pure charcoal remains, and vinegar mixed with water, tar, and some substances besides, pass over, and are collected in a proper receiver.

You appear astonished at my saying that vinegar is procured from wood, but this is the source of the very strongest vinegar, called pyroligneous acid. *Pyroligneous* is a Greek word, signifying fire and wood. Well, I shall now leave charcoal, and pass on to another form of carbon, called plumbago, or black-lead, much used for making pencils and for blacking grates. Black-lead, then, contains no lead at all, but is carbon, almost pure; sometimes, however, there is present a little iron.

I dare say you are tired of charcoal and of black-lead, too; I readily own there is nothing very prepossessing in the appearance of either of them, although both are more useful than the much-admired diamond, respecting which I have now something to tell you.

The diamond, called by the ancient Greeks *adamas*, by the Persians *almas*, and by the inhabitants of India *heera*, has been known and valued from a period of very great antiquity. Pliny mentions it as being the most valuable of human possessions, and says, " that ancient writers describe it as found only in Ethiopia, between the island *Mera* and the *Temple* of Mercury." He then goes on to say, that " lately it has been brought from India; that it is incapable of being heated in the fire; from which property, together with its extreme hardness, the Greeks called it *adamas*, unconquerable." Pliny then tells us, " that naturally the diamond cannot be broken into fragments; but this may be done after soaking it in the blood of a *he goat!* and that the fragments so procured are very valuable for engraving on other gems. He affirms, that the diamond and the magnet have a great antipathy for each other, so that the latter cannot attract iron when in contact with the former: also that the diamond destroys the effect of poisons, and cures insanity." Well, really, I have hardly patience with Pliny for writing such nonsense; you need not be told that the diamond is not softened by goat's blood, neither does it cure insanity, nor prevent the magnet attracting iron.

We may learn from Pliny, however, one fact, that diamonds had not long before his time been brought from India. A part of the world which furnished the exclusive supply of diamonds from the time of Pliny until the year 1728, when this gem was found in Brazil. The ancients valued diamonds on account of their hardness; the method of giving them a beautiful polish was only discovered in the year 1746, before which time they were used as ornaments in their native and unpolished state; at least in European nations:—the inhabitants of India possessed the art of giving diamonds an imperfect polish at a much earlier period.

As soon as the Arabians had conquered Spain, and had introduced into Europe the wild fictions and romantic notions of eastern climes, the value of gems increased; they were thought to have an alliance with beings of another world, and to be endowed with the most extraordinary powers. The diamond in all these respects was ranked as pre-eminent; it was worn on the person as a charm or amulet, and was considered to guard its possessor against poisons, witchcraft, insanity, and evil spirits.

These superstitious notions (thanks to the spread of information) have long since been discarded, and we attribute to the diamond no such mysterious properties; still its nominal value is just as great as ever.

As an article of real utility, the diamond is of no great importance, its use being chiefly confined to the polishing of gems and the cutting of glass,—but owing to its extreme beauty it is still sold at a most exorbitant rate.

There is a regular scale of value for these gems according to their weight, but it is scarcely applicable to very large diamonds, which would come to sums so enormously great that no purchasers could be found sufficiently rich to buy them.

The Pitt or crown-diamond of France, if valued according to the strict rule, is worth £141,058. It was found at Pasteal in Golconda, and was purchased by Mr. Pitt, the governor of Madras, for a sum equal to about £20,000 of our money. In the year 1717, he sold it to the Regent of France, as a crown-jewel, but Napoleon had it set in the hilt of a sword of state.

The Emperor of Austria possesses a very large lemon-coloured diamond. It was purchased at a stall in the market-place of Florence for a few pence, as it was thought to be a piece of rock-crystal.

The Emperor of Russia possesses a large diamond, the history of which is very curious. It once formed the eye of an Indian idol, and a French soldier having taken a fancy to it, he became priest to the deity; in which capacity he managed to extract the diamond eye, and to replace it with a glass one. Escaping with his treasure, he sold it at what *he* considered a good price, but which was in reality a very low one. The jewel, after passing through a great number of hands, was purchased by the Empress Catherine of Russia, who gave a sum of ninety thousand pounds for it, besides an annuity of four thousand pounds as a further remuneration! The Great Mogul possesses a diamond larger than either of these: it is of a rose-colour, and was found in Golconda, in the year 1550.

But the largest diamond is in the possession of the royal family of Portugal; its value, if estimated according to the common rule, would be nearly two million pounds sterling! However some persons doubt whether it be a diamond or only a white topaz.

The diamond is the hardest of all known substances, and therefore can only be cut or polished by rubbing it against another diamond, hence we have the phrase "*diamond cut diamond*," when one rogue tries to cheat another.

Long before people were aware of the diamond's actual composition, Sir Isaac Newton suggested that it might contain combustible matter, from observing that it powerfully refracted, or bent from a straight course, rays of light. He termed it *an unctuous substance coagulated.* In the year 1763, our celebrated countryman Boyle proved that the diamond might be converted into vapour by a heat not exceeding that required to melt copper. Cosmo III., Grand Duke of Tuscany, succeeded in burning diamonds by concentrating on them the sun's rays by a burning-glass; and the French chemist, Lavoisier, first proved that they contained carbon.

Notwithstanding the extreme beauty of the diamond, one cannot but feel astonished that it finds purchasers at a rate so enormous, especially when we remember that this proud, this imperial ornament, which has ever occupied the seat of a diadem, is after all but a morsel of charcoal which has been made to yield to the rays of the sun and to dissolve into a noxious vapour.

LECTURE VIII.

SULPHUR—SELENIUM—PHOSPHORUS—BORON—SILICON.

On viewing those large yellow lumps which are lying on the table, your imagination involuntarily paints to you a bundle of brimstone matches, and those poor, unfortunate, squalid creatures who carry them about. What is there interesting in sulphur? you say to yourselves—why devote our precious time to the study of a substance which is used for matches? Oh! entertain not those thoughts, they are unworthy of you all. Sulphur would stand high in the scale of chemical interest, as being one of the fifty-four simple bodies, had it no further claim to our attention; but besides entering into the composition of oil-of-vitriol, the uses of which are innumerable, it is employed in bleaching, medicine, and war. Without sulphur the ladies could not have white straw bonnets, for by it are they bleached: without sulphur we could neither cure certain diseases nor repel our foes, for it is used in medicine, and in the manufacture of gunpowder; without sulphur the flint and steel would throw their sparks in vain, and the cottager's hearth would not be gladdened by the blaze of a cheerful fire; nay, without sulphur, probably, we could not exist, for in small quantities it enters (vile as you think it) into the composition of our own bodies.

Sulphur is one of the few simple or elementary substances which is found to exist in an uncombined state. In the neighbourhood of volcanoes vast quantities occur almost pure. The best sulphur comes from Sicily, but a great deal of it is procured in Cornwall, where it exists in combination with various metals, and is separated from them by means of heat. Sulphur is sometimes melted and cast into rolls, when it obtains the name of roll sulphur; at other times it is put into an iron vessel, and exposed to heat, which operation causes some of it to rise in the form of powder; this powder is called flowers of sulphur, and is by far the purest kind.

Nearly resembling sulphur in many of its properties is the substance called selenium, which was discovered by the celebrated Swedish chemist, Berzelius. Selenium is so called from *seléne*, a Greek word, meaning the moon: but selenium has nothing at all to do with the moon; it derives its name from the following circumstance. There is a metal called tellurium, from *tellus*, a Latin word, meaning the earth; why so called I am sure I cannot tell—chemists are often very fanciful in giving names to substances which they discover, and here is an instance. Well, this selenium was once mistaken for the metal tellurium, and when the mistake was discovered, and the new substance was found to be different from tellurium, they called it selenium, after the moon. Almost the only person who prepares selenium is its original discoverer, Berzelius. After some trouble I have obtained a very small specimen of it, which has come all the way from Sweden, and as you observe, is stamped with the name of Berzelius.

Selenium is more curious than important, and perhaps you will never see a sample of it again, therefore I shall say no more about it.

The next simple body I shall describe is phosphorus, a substance not less curious than dangerous.

Phosphorus was discovered by a German chemist, named Brandt, in the year 1677, during his search after the philosopher's stone. Brandt told Kraaft of Dresden how to make it, but would not communicate the process to Kunkle, who, however, set to work and discovered it himself, and the substance was long known by the appellation of *Kunkel's phosphorus.* In the year 1679 Kraaft took the trouble to come over to this country in order that he might show a piece of phosphorus to the British king and queen. Whilst he was here, our countryman, Boyle, first saw phosphorus, and whether Kraaft acquainted him with the process of making it is not certain ; if not, he must have discovered the process himself, for he very soon *did succeed* in preparing it.

Phosphorus, when pure, is nearly colourless, and about the consistency of wax. Its most curious property consists in bursting into flame by the application of a heat little exceeding that of the human body, on which account it must be handled with great caution, and never be kept out of water for more than two or three minutes at a time.

A piece of phosphorus if carried into a dark place emits a faint glimmering light; and if letters be written, or figures be drawn with this substance they shine in the dark: however, I shall not perform the experiment, nor would I advise any of you to do so, as the mere friction against a hard body is very likely to set the phosphorus on fire, and I have seen many a frightful accident from this cause. There is a method of exhibiting the illuminating property of phosphorus with perfect safety. If a piece of it be put into a bottle together with sulphuric ether, there is obtained a solution, which, if rubbed over the face and hands, causes them to appear on fire, without the possibility of giving rise to an accident.

Such then are the properties of phosphorus; and who would have dreamed of its existence in animals? not only *does it exist* in them, but it seems absolutely *necessary* to the higher grades of life. United with lime and oxygen in a peculiar way, it constitutes the greater part of bones, from which it is now almost exclusively obtained. In nothing is the power of the Almighty more evidenced than in gaining his ends by means which to us seem least adapted to the purpose. If a person acquainted with the properties of the fifty-four chemical elements had been desired to mention one, which, in his opinion, might be least adapted to enter into the composition of animal substances, and especially bones, he certainly would have fixed on phosphorus, a substance which is no harder than wax, and which bursts into flame at much lower temperatures than those which are frequently experienced by animals. Yet, through Almighty power, these characteristics of phosphorus in a simple state are altogether lost in the hard, and incombustible phosphate of lime, which constitutes the greater part of bony matter.

Boron is an elementary substance, which is procured from borax ; it is a solid, possessing an olive colour, but I have never seen it, nor have most other persons, I believe ; therefore let us pass it over.

Silicon* is an elementary substance which is procured from flints. The compounds of this substance are very important, and I shall speak of them in their proper place ; in its uncombined state, however, silicon is merely interesting as a chemical curiosity—so difficult to procure that I cannot even show you a specimen.

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* There are some persons who imagine this substance to be a metal, and by them it is termed *silicium*.

LECTURE IX.

COMPOUNDS OF THE NON-METALLIC SIMPLE SUBSTANCES WITH EACH OTHER—OXYGEN AND NITROGEN.

OXYGEN and nitrogen unite in six different proportions to form as many different combinations. One, however, is regarded by most persons to be a mechanical mixture, and not a chemical compound—I mean the atmosphere.

THE ATMOSPHERE.

The atmosphere, or air which we breathe, I need not inform you was one of the elements of the ancient Greeks and Romans, and its compound nature was only demonstrated in the year 1774. Now, as to the properties of the atmosphere, I need not tell you it is colourless, and without tase or smell. From the calculation of Dr. Wollaston and other philosophers, the atmosphere is presumed to be forty-five miles high, or, to speak in other words, the earth is supposed to be surrounded with a layer of air forty-five miles in thickness; how this conclusion is arrived at I shall not at present tell you, because if I did you could not follow me through the calculation.

In scientific books you will read that the atmosphere presses with a force of fifteen pounds on every square inch; by which is meant, that if you could take a tube or pipe, having an aperture exactly equal to a square inch in size, and if this tube were forty-five miles long, so that on fixing it vertically, or upright, one end of it might rest on the sea, or on a part of the earth level with the sea, and the other end extend to the farthest limits of the atmosphere, then the quantity of air contained in this tube would weigh fifteen pounds. I need hardly tell you that a square inch is a square, each of whose sides is an inch in size.

Well, then, a column of air forty-five miles high and an inch square weighs fifteen pounds, which is equal to the weight of a column of water an inch square and thirty-four *feet* high, or a column of the metal quicksilver an inch square and twenty-nine *inches* high: you will see the use of this information by and bye.

Now, if the atmosphere be so heavy it must exert great pressure upon our bodies: I think I hear you say to yourselves,—to be sure it does; a moderate-sized man perhaps contains two thousand two hundred square inches of surface, consequently the atmosphere presses upon him with a force of thirty-three thousand pounds!* We are all of us, then, subjected to an enormous weight, without which we, however, could not exist, for it prevents the fluids of our bodies being dissipated in vapour, when the soft parts would dry and crumble into powder.

I shall now speak of another property of the air,—its elasticity. You know very well that, by exerting sufficient force, a piece of India-rubber may be pulled out to three or four times its natural length, but immediately this force is removed, it returns to its original dimensions; this property is termed elasticity. Well, the air is elastic, and, indeed, so are all other gaseous substances. It is very true you cannot grasp the atmosphere, and pull it out like you would a piece of India-rubber, but you can do that which amounts pretty nearly to the same thing.

Put the neck of a small bottle in your mouth, and suck out as much air as you can;

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* There are some who estimate the atmospheric pressure on a moderate-sized man to be forty thousand pounds.

then, on pulling the bottle suddenly away, you hear the air, which had been removed, return again to the bottle, with a slight noise. One may also by means of the mouth force into the same bottle more air than it is naturally capable of containing, when, on removing the bottle, this excess of air will be heard to escape; both those experiments prove that the air is elastic.

By means of the mouth, only a small quantity of air can be removed from a vessel; but there is an instrument, called the air-pump, which is capable of removing *nearly* the whole of it, although never quite the whole.

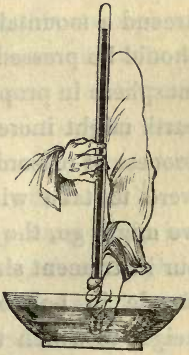
By a mechanical contrivance, which exerts much greater force than can be commanded by the mouth, a given quantity, or measure of air, may be compressed into a space many times less than it occupies naturally, and if afterwards allowed to escape, it does so with prodigious violence;—on this principle depends the air-gun.

I must now request that you will pay great attention, for I am going to lead you to some very important conclusions, from the facts which we have been considering. Since the atmosphere is forty-five miles high, and since it presses upon every thing with a force of fifteen pounds on the square inch, it is quite clear that it must press upon itself. In order to illustrate what I mean, let us imagine that instead of a layer of atmospheric air, forty-five miles high; a heap of feather-beds of the same height. Is it not certain that the one nearest the ground would be pressed upon by the whole which might be piled up above it? Is it not evident, moreover, that the lower feather-bed would be pressed into a much smaller space than the upper one? or, to speak in philosophic language, would be more dense? Certainly:—well, this is precisely the case with respect to the atmosphere; the lower part of which is pressed upon by the whole of that which is above, and consequently is the more dense of the two. Hoping that you all understand what I have been saying, I shall now proceed to teach you the nature of the barometer, which is an instrument for ascertaining the *weight of* the atmosphere.

About the BAROMETER.—Do you not remember my informing you, whilst we were engaged in preparing oxygen, that if you inverted a bottle full of water into a basin also containing water, the water in the bottle would not come out? Yes, I am sure you remember it; but perhaps you do not understand the reason: however great the length of the bottle may be, provided it do not exceed thirty-four feet, still, I say, the water *will not* come out; but if the bottle were to be longer than thirty-four feet, then the water *would* come out. If instead of water we employ the liquid metal, quicksilver, then the limit to the length of our bottle is not thirty-four feet, but only thirty inches.

Do not accuse me of talking nonsense—*I* never saw a bottle so enormously long as thirty-four feet, or even as thirty inches, and I only say what I do in order to make you understand a principle. Can you give me the reason of all those facts? No. Then I will tell you. The reason why water did not come out of the bottle, is because the pressure of the atmosphere kept it there: a column of water thirty-four feet high, and a column of mercury or quicksilver thirty inches high, are each of them equal to a column of atmospheric air of the same size, and forty-five *miles* high: therefore it is that the columns of quicksilver and of water, of the heights just mentioned, are balanced by the atmosphere; but if they exceed those heights, then they become heavier than the atmosphere, which will consequently no longer support them, and they fall. When trying to understand the mechanism of the instrument, you should look at it in its simplest form; so many additions are frequently made to an instrument for mere ornament, and so many for slight conveniences, that its original character becomes lost. If, for instance, I had to explain the mechanism of a church organ, my first care would be to inform you that those large gilt pipes so conspicuous in front were merely intended for show, and not for use. Well, I shall now describe to you a barometer in its simplest form.

Take a thick glass tube, about thirty-five inches long, closed at one end, and open at the other, fill this tube quite full of quicksilver, and also pour some quicksilver into a basin or finger glass. Now, having covered the open end of the tube with your fore-finger, invert it into the mercury in the basin. When you feel that your finger has descended considerably below the surface of the mercury, remove it from the mouth of the tube, and I scarcely need tell you what follows, for of course you remember that the atmosphere does not support thirty-five inches of mercury, but



only thirty, consequently the mercury in the tube will fall five inches. I have not hitherto informed you that although the usual pressure of the atmosphere at the level of the sea is fifteen pounds upon every square inch, yet it varies a little, being sometimes more, and at other times less: when it is more, then will a pressure be exerted on the surface of the mercury in the basin greater than fifteen pounds on the square inch, and consequently the mercury will rise higher than thirty inches in the tube. On the other hand, when the atmosphere presses less, then will the mercury sink lower than thirty inches. I think it was proved by means of our feather-beds, that if we were to ascend a mountain, or to go up in a balloon, we should be pressed upon less and less by the atmosphere in proportion as our distance from the earth might increase; therefore, by the same process of reasoning, it is evident that if we were to take with us a barometer, the higher we might go, the lower would the mercury in our instrument sink. This is the very way that people in balloons manage to ascertain the height to which they have ascended; for the rate at which mercury sinks at various heights has been determined, and may be seen by inspecting a table drawn up for the purpose of affording the necessary information. The instrument which I have just shown you how to make represents the barometer in its simplest, and, indeed, its most perfect form; all other alterations are either for the purpose of rendering the instrument more easy to be carried about, or more ornamental.

The barometer is sometimes called a weather-glass, because it is found that the mercurial column generally falls when the air contains much moisture, and rises when the air is dry, hence it becomes, to a certain extent, a foreteller of rain or of dry weather, as the case may be.

Having said so much about this atmospheric pressure, I will relate to you an anecdote respecting its discovery. Cosmo the Second, Grand Duke of Tuscany, wished to pump water from a very deep well, but having erected his pump, it was found that the water would not rise. This circumstance very much surprised his highness, and he called together the philosophers, in order that the mystery might be solved. Now the hitherto received opinion of the rise of water in a pump was, that nature abhorred a vacuum: but why, then, should nature be so unkind to Cosmo, Grand Duke of Tuscany?

The pump-makers were now questioned, and they affirmed that water never *would* rise more than thirty-four feet; why, they could not tell. In this state matters remained, until Torricelli, a pupil of the celebrated Galileo, undertook the investigation of the subject, and he made the important discovery, that just as water could not be pumped more than thirty-four feet, neither could quicksilver be pumped more than thirty inches; and by this time, if I mistake not, my young friends have come to the same conclusion as did the philosopher Torricelli;—namely, that it is atmospheric pressure alone which causes water to rise thirty-four feet in a pump, and prevents its rising higher. In order that you may more clearly understand what I have been saying, I will describe to you those diagrams, which are intended to represent a pump in various stages of action.* The sketches I now show you represent a pump in its very simplest state; the mere skeleton of a pump, so to speak.

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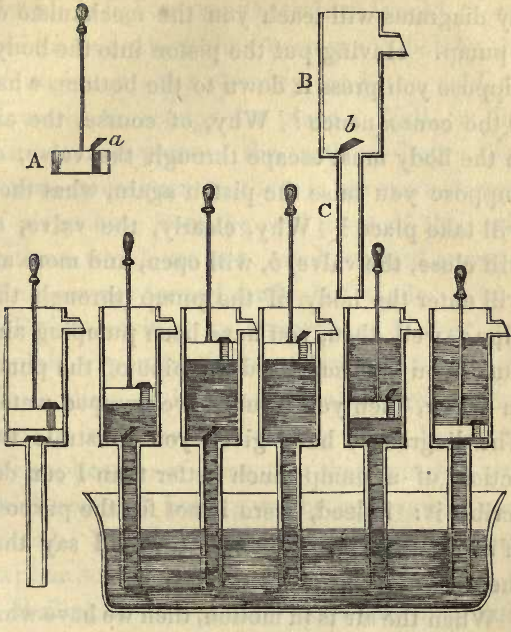
* The pump was unknown to the ancient Greeks and Romans, also to the Chinese, Indians, and Egyptians:—invented by Ctesibius of Alexandria, 120 years B. C.



The parts of a pump are, the piston, or sucker, A; the body of the pump, B; and the pipe, C. The piston or sucker is made of wood, covered with leather, and exactly fits the body, B; this sucker has a hole bored through it, which is covered by a trap-door, *a*, called a valve: the body of the pump has also a valve, *b*.

I think, then, that a minute's inspection of my diagrams will teach you the mechanism of a pump. Having put the piston into the body, suppose you press it down to the bottom, what is the consequence? Why, of course, the air in the body must escape through the valve, *a*. Suppose you raise the piston again, what then will take place? Why, clearly, the valve, *a*, will close, the valve, *b*, will open, and more air will enter the body of the pump through the pipe: well, then, you have been pumping air; but if you had immersed the pipe of the pump in water, then you would have pumped water. The diagrams I have given you illustrate the action of a pump much better than I can describe it: indeed, were it not for the purpose of avoiding a little blunder, I would say that the drawings speak for themselves.

When the air is in motion, then we have what is called wind. The nature of winds I think I can explain to you in a very easy manner. On a cold day, if you sit in a room which contains a good fire in an open grate, you find that through every chink and crevice, such as the key-holes, and the spaces between the door and doorposts, there blows a cold current of air, or wind, called in ordinary language a draft. This draft depends on the following circumstance.

Hot air is lighter than that which is cold, therefore that air which has been made hot by the fire rushes up the chimney, and the cold air blows in to occupy its place. Well, in like manner some parts of the earth are hotter than others, consequently there is always a current of air rushing from the cold parts of the earth to those which are hot; such natural currents of air are not termed drafts, but winds.

Before leaving the atmosphere, I must just explain to you the influence which it has over the boiling of liquids. Persons are so frequently in the habit of seeing water boiled by the application of heat, that they imagine artificial heat and boiling to be necessarily connected. No such thing, as I shall presently explain to you.

Boiling is merely the conversion of a fluid into steam with such rapidity as to be attended with bubbling. Were it not for the atmosphere, all liquids in nature would undergo this rapid conversion into steam, or, in other words, would boil; for there does not exist a ponderable substance without *some* heat, although it may appear to us quite cold; and the natural tendency of heat is to cause the formation of steam, which would therefore ascend from water, as well as from every other liquid, were it not for the atmosphere, which by exerting an immense pressure, keeps this steam down, and of course prevents boiling. Liquids then may be made to boil by two methods. We may either take away atmospheric pressure, and allow the natural heat of the liquid to act; or we may add so much additional heat as may be necessary to overcome the atmospheric pressure; and this you know is the common plan.

Without the atmosphere neither can animals live nor fires burn: of all the gases that we have hitherto prepared, none could supply the place of the atmosphere. Oxygen would intoxicate us, and set the world on fire:—nitrogen would kill us on the instant when breathed; and how terrible must be the consequences if we were surrounded with an atmosphere of chlorine! Yet one word of the Almighty might do all this! in an instant he might abstract either of the gases which form the atmosphere; or from the mild and useful sea-salt, he might let loose the suffocating chlorine, which would soon destroy all vegetation, and kill in excruciating agonies all breathing creatures.

I need not remind you of the utility of winds: they disperse the hovering emanations of disease,—they work our mills,—and they waft to us the luxuries of foreign lands. From the gentlest zephyr that allays the summer's heat, to the terrific hurricane which tears up forests in its course, every variety of wind has its own peculiar use, and ministers to some good end; but what this use or end may be our imperfect understandings cannot always discover. The rank emanations from decaying animals and vegetables under the influence of a tropical sun, may require no less than a hurricane to sweep them away, whilst the less noxious effluvia of temperate climes may be dispersed by the gentler breeze.

The meaning of the term specific gravity I have already explained to you; but again I repeat, that it is the comparative weight which substances have to each other. Gases are compared with the atmosphere; liquids and solids with water. If a gas be said to have a specific gravity of three, it is meant that a certain quantity, by measure, of this gas, weighs three times heavier than an equal quantity, by measure, of atmospheric air. This method of taking the specific gravity of gases is easy enough in theory, but as an air-pump is necessary for performing the operation, I can only describe it. A flask supplied with a stop-cock is first weighed, when full of air; afterwards the air is removed by the air pump, and the flask is again weighed. It is now filled with the gas whose specific gravity is to be tried, and once more weighed. By the first and second operations we learn the weight of the flask, and of the air which it contains;—by the third we ascertain the weight of the gas which it can hold.

Suppose the flask when full of air weighs ten grains, and when full of gas twelve grains. Now if the weight of the flask alone be nine grains, it is evident that the gas weighs three times as much as an equal measure of air, or, in other words, that the specific gravity of the gas is three.

I now conclude the subject of the atmosphere, and when we meet again I will proceed with the other compounds of nitrogen and oxygen. The first I shall describe is the laughing-gas, the experiments with which you will find exceedingly amusing.

As might have been expected, our curiosity to witness the effects of the celebrated laughing-gas, made us all very punctual in attending the next Lecture; scarcely a person in our village was absent: old and young, rich and poor,—all came in expectation of great fun. The table was covered with a profusion of bladders, which were intended to be filled with gas, and then breathed from. The old gentleman himself seemed to be as much pleased as his young friends; his natural grave expression of countenance had given place to an arch smile, and he seemed to share with us in all our glee. For some time before our arrival he had been busily engaged in preparing the gas, many bladders full of which were already collected; but some were empty, in order that we might go through the process of filling them ourselves. Having put the instruments a little in order on the table, he recommenced his discourse.

LECTURE X.

PROTOXIDE OF NITROGEN—OTHERWISE CALLED NITROUS OXIDE, OR LAUGHING-GAS.

Besides the atmosphere, nitrogen combines with oxygen in five different proportions, to form as many different compounds, the composition and name of which you may see by this diagram.

Nitrogen.	Oxygen.	
14	8	Protoxide of Nitrogen—Nitrous oxide, ——— or, Laughing-gas.
14	16	Binoxide of nitrogen—Deutoxide of nitrogen, ——— or, Nitric oxide.
14	24	Hyponitrous acid.
14	32	Nitr*ous* acid.
14	40	Nitr*ic* acid.

From which you see that fourteen parts by weight of nitrogen may combine with eight parts by weight of oxygen;—with sixteen, or twice eight parts;—with twenty-four, or three times eight parts;—with thirty-two, or four times eight parts;—and with forty, or five times eight parts of oxygen, and form five different compounds. Now fourteen parts of nitrogen will not combine with *less* than eight of oxygen, nor with any number of parts of the same substance *between* eight and sixteen —sixteen and thirty-two—thirty-two and forty —or, in short, with any other number of parts of oxygen besides those which are put down in the table.

There is something very curious about this, and philosophers can only account for the fact, by supposing that all substances in nature are made up of little particles or atoms, so immensely small that we can never hope to see them, nor to know their exact weights, although by a process of indirect reasoning we may ascertain how much heavier one atom is than another.

For instance, it is found that whenever one part by weight of hydrogen enters into a compound, its place cannot be supplied by less than fourteen parts by weight of nitrogen; sixteen of sulphur and of phosphorus; eight parts of oxygen, and so on for every other element. The atom of hydrogen, then, is said to weigh one, that of nitrogen, fourteen; of sulphur and phosphorus, sixteen, and of oxygen, eight. Consequently the numbers one, fourteen, sixteen, eight, are said to represent the atomic weights of those substances respectively. But as we are not *quite*, although *very nearly* certain about the existence of those little atoms, some people think it improper to use the term atomic weight, because something that we cannot absolutely prove is taken for granted; such persons prefer the term *equivalent* weight; both expressions however have the same meaning, and are often used indiscriminately.

Granting that atoms do exist, let us apply the theory to our present subject. As the atomic or equivalent weight of nitrogen is fourteen, and that of oxygen is eight, we may state the five compounds of nitrogen, and oxygen as is done in this diagram.

Nitrogen.	Oxygen.	
1	1	Protoxide of Nitrogen.
1	2	Binoxide of Nitrogen.
1	3	Hyponitrous Acid.
1	4	Nitrous Acid.
1	5	Nitric Acid.

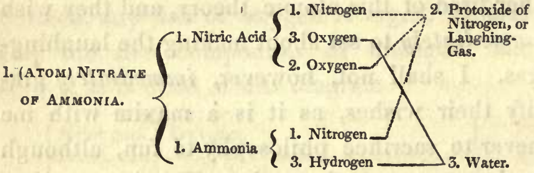
According to which statement it appears, that the smallest possible quantity of protoxide of nitrogen, commonly called laughing-gas, is composed of one atom, or equivalent of nitrogen in union with one of oxygen. The smallest possible quantity of binoxide of nitrogen, of one of nitrogen combined with two of oxygen, and so on.

Such then is the first outline of the atomic theory. I have not found an opportunity of introducing it before, and, indeed, I had some idea of omitting it altogether, lest you might be frightened at its long name; but I think you will agree with me in the opinion, that there is nothing in the least difficult about it.

If I mistake not, my young friends are rather tired of this atomic theory, and they wish *immediately* to set about making the laughing-gas. I shall not, however, *immediately* gratify their wishes, as it is a maxim with me never to sacrifice philosophy to fun, although both are very good together. This is especially necessary in the present instance, for if you do not understand the philosophy of the laughing-gas before you breathe it, I am sure you will not afterwards; at least, not during this Lecture.

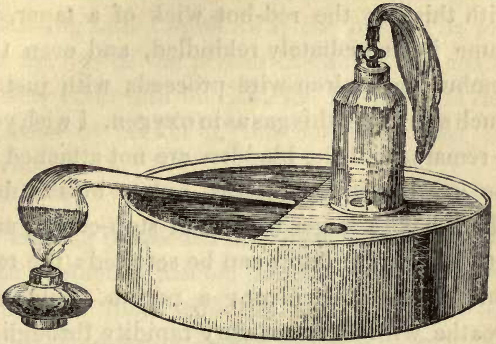
It is composed, then, of one atom of oxygen and one of nitrogen, and is named *proto*xide from the Greek word *protos*, meaning *first*, because it is the first or smallest combination of oxygen with nitrogen. It cannot be made by mixing oxygen and nitrogen together, but it is procured by distilling a substance called nitrate of ammonia.

Nitrate of ammonia is a salt composed of nitric acid and ammonia. Nitric acid is made up of nitrogen and oxygen, and ammonia of nitrogen and hydrogen. If we apply heat to this nitrate of ammonia it is converted into water, and laughing-gas, or protoxide of nitrogen: the diagram I here give you explains how the change is effected.



It appears, then, that on applying heat to nitrate of ammonia, water, and protoxide of nitrogen, or laughing-gas, are formed. If one atom of nitrate of ammonia be employed, then we shall get three atoms of water and two of laughing-gas. Those diagrams for expressing chemical changes are just getting into fashion, and they are certainly far more convenient than mere words.

But I see you are all impatient to set about the process, and I will keep you in anxiety no longer.



Some nitrate of ammonia has already been put into a half-pint glass retort, the beak of which is placed under the shelf of a pneumatic-trough, *near* a proper receiver. I now apply the flame of a spirit-lamp:—already the salt begins to melt, and now there escape from it bubbles of gas, which rise through the water, and are lost. Those first portions of the gas having passed away, I put the beak of the retort under the receiver, and collect the pure gas which next comes over. The nitrate of ammonia is only to be kept *simmering* not violently *boiling*, for in that case a very injurious gas would pass over, which may be known by its red colour; it is called binoxide of nitrogen

Laughing-gas supports combustion nearly as well as oxygen: on plunging into a jar filled with this gas the red-hot wick of a taper, its flame is immediately rekindled, and even the combustion of iron wire proceeds with just as much activity in this gas as in oxygen. I wish you to remark, that the bladders are not attached to the stop-cocks themselves, but to brass tubes which have a larger bore than stop-cocks, and into which the latter can be screwed: the reason for this is evident; a person could not breathe with the necessary rapidity through a stop-cock, its apperture being so very small.

It is called laughing-gas from the peculiar effect it produces when breathed; not that it always causes laughter, but it usually gives rise to such whimsical contortions of the features, and causes persons to play such ridiculous antics, that if the operators do not themselves laugh, those who look on certainly must: the claim then of this protoxide of nitrogen to the name of laughing-gas is very fairly earned.

The person who breathes it must proceed in the following manner:—holding his nose tight between his fingers and thumb, he must forcibly expel from the lungs as much air as he can, then he must breathe from, and into a bladder filled with the gas until its peculiar effects are experienced, which probably may be in about half a minute. There should be some person standing near to pull away the bladder as soon as the lips of the person breathing the gas are observed to turn blueish, for it might be dangerous to persist in the operation after this symptom.

Having proceeded thus far in his Lecture, the old gentleman handed round a great number of bladders filled with the gas; and here our short-hand writer ceased from his work. Anxious to enjoy the fun as well as the rest, his office of scribe did not hinder him from seizing a bladder too: for my part I determined to have some amusement of another kind, in witnessing the effects produced by the gas upon others, without breathing any myself; and, perhaps, I laughed more than either of the breathers. Oh, how shall I describe the scene which followed? For one instant, the silence of our Lecture-room was only broken by the deep-drawn inspirations of those who were breathing the gas: all seemed to be enjoying the extreme of happiness, they puffed and pulled as if they could not get enough. It was, indeed, irresistibly ridiculous to see a large room filled with persons, each of whom was sucking from a bladder, and this alone made me laugh right well; but in another instant began their ecstacies, some cast their bladders from them with a jerk, and, forgetting the ridiculous figure they made, kept breathing laboriously; their mouths thrown wide open, and their noses still tightly clenched: some jumped over the tables and chairs; some were bent upon making speeches; some were very much inclined to fight; and one young gentleman persisted in attempting to kiss the ladies. I have heard it insinuated that he breathed very little of the gas, and that he knew very well what he was doing; but this statement I consider to be untrue. As to the laughing, I think it was chiefly confined to the lookers-on.

A few minutes served to restore those maniacs to their senses, and they felt as if nothing had occurred; for it is a peculiarity of this gas, that it does not act like intoxicating liquors in producing depression of spirits, disorder of the stomach, or indeed any other unpleasant effects.

As our instructor had predicted, we did not after this exhibition feel very much inclined to study philosophy, and therefore the Lecture, although short, was brought to a conclusion.

LECTURE XI.

BINOXIDE OF NITROGEN, OR NITRIC OXIDE—HYPONITROUS ACID—NITROUS ACID—NITRIC ACID.

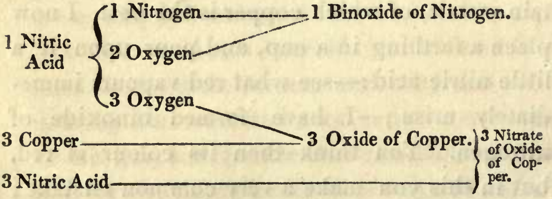
If my young friends are all recovered from the effects of the laughing-gas or *prot*oxide of nitrogen, they will now be prepared to follow me, in my description of *bin*oxide.

This also is a gas, and is procured by adding nitric acid, commonly called aquafortis, to certain metals, of which copper is the best. I now place a farthing in a cup, and pour upon it a little nitric acid:—see what red vapours immediately arise;—I have formed binoxide of nitrogen. You think then its colour is red, but in this you make a very common mistake; binoxide of nitrogen is colourless, although it forms red vapours immediately on coming in contact with atmospheric air, or any other gas which contains oxygen. I will now make some in another manner, and prove to you that it is entirely without colour.

I put some small pieces of copper into a retort, and pour upon them a little nitric acid. Having done this, I immerse the beak of the retort under water, and apply gentle heat. The retort is first filled with red fumes, because the gas is mixed with atmospheric air; but those fumes soon subside, and binoxide of nitrogen may be collected in a proper vessel, quite free from colour.

If to a receiver partly filled with this gas some atmospheric air be added, then the red fumes will immediately reappear.

We will just have the theory of making this binoxide of nitrogen, and then leave it altogether.



The changes which ensue are represented by the diagram.

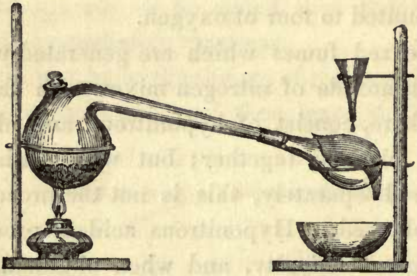
It appears that nitric acid is composed of oxygen and nitrogen. Copper takes away part of the oxygen in order to form oxide of copper, and the remaining oxygen uniting with the nitrogen, forms the gas which we are engaged in investigating.

How much better are those changes expressed by a diagram than by words! *Hypo*-nitrous acid derives its name from the Greek word *upo*, under, because it contains less oxygen than nitrous acid. It is composed of one atom of nitrogen, and three of oxygen.

Nitrous acid is another combination of nitrogen and oxygen, composed of one atom nitrogen, united to four of oxygen.

The red fumes which are generated whenever binoxide of nitrogen mixes with the atmosphere, consist of hyponitrous and nitrous acids blended together; but when either is required separately, this is not the process to be followed. Hyponitrous acid is procured with great difficulty, and when obtained possesses very little interest. Nitrous acid may easily be obtained by distilling the salt called nitrate of lead, but its uses and interest are not great. I shall not go through the processes for making either of them, but pass on to nitric acid, which is by far the most valuable of all the chemical compounds formed by the union of nitrogen with oxygen.

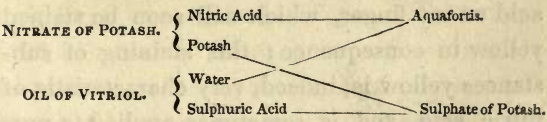
Most of you, I dare say, have seen nitric acid, or aquafortis, although you may be unacquainted with the method of preparing it. Into a half-pint stoppered glass retort I put about half-an-ounce of saltpetre, the chemical name for which is nitrate of potash, and I pour upon it half-an-ounce, by weight, of strong oil-of-vitriol, which, in chemical language is called sulphuric acid. I now place the retort upon a chemical stand, and put its neck into a clean Florence flask.



The retort must be made hot and the flask, or receiver, kept very cool. For the purpose of applying heat I shall use a spirit lamp; and I think the best way of keeping the receiver cool is to cover it with blotting paper, which is preserved wet by the continual dripping of cold water. It does not matter how this water is made to drop: I might effect it by squeezing over the flask a wet sponge; but the most convenient method is to place above it a funnel, into the neck of which is inserted a notched cork, and which is filled with water; by this little contrivance the flask may be preserved quite cold.

I now apply to the retort the flame of a spirit-lamp, and in a very few minutes nitric acid, or aquafortis will condense in the flask.

Suppose we now have the theory of the process. Saltpetre, or nitrate of potash, is composed of nitric acid and potash; oil-of-vitriol, of sulpuric acid and water: sulphuric acid takes away the potash to form sulphate of potash, and nitric acid passes over in combination with water. Aquafortis and nitric acid, then, are only two names for the same thing, or, to speak more correctly, aquafortis is nitric acid, combined with water.*



There has now passed over as much nitric acid as is necessary for our purposes, and we will proceed to test it, or to try some of its properties.

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* It is impossible to obtain nitric acid in an isolated form. It must be combined with *something*, or else it cannot exist: this *something* may be water. Consequently, aquafortis is the simplest form under which we can obtain nitric acid, being a union of the actual acid with water.

In the first place, then, I wish you to observe it is very nearly colourless: the aquafortis of commerce, I grant, sometimes appears red, but this is owing to an impurity; *we* have succeeded in manufacturing a purer article. I wish you also to remark that nitric acid has a very strong and penetrating smell.

I now dip into this acid a piece of blue litmus paper, which you observe is immediately reddened: this is a test for acids in general, most of which redden litmus paper.

Here is a little crystal of a substance called *morphia*, on which I drop some nitric acid; see how red the morphia becomes.

I have, unintentionally, spilt a little of this acid on my finger, which will soon be stained yellow in consequence: this staining of substances yellow is, indeed, very characteristic of nitric acid, and is sometimes applied to purposes which are exceedingly useful. Have you not observed those yellow borders which surround baize table-covers? they are produced by the action of nitric acid.

I now drop a little of the acid on a piece of copper, and red fumes immediately appear.

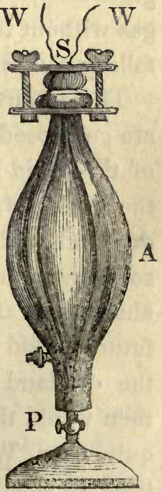
You would then be certain that a liquid was nitric acid if it stained animal substances yellow, reddened morphia, and produced red fumes when dropped upon copper.

Nitric acid is a substance of great importance: it is used very largely in medicine and the arts; and without it the scientific chemist would be unable to conduct some of his most important operations.

LECTURE XII.

COMPOUNDS OF HYDROGEN AND OXYGEN—WATER, PEROXIDE OF HYDROGEN.

Hydrogen unites with oxygen in two proportions, forming two different compounds. One is water, or protoxide of hydrogen, and the other is called peroxide of hydrogen. I have already explained to you how it may be proved that water is composed of hydrogen and oxygen: there is yet another method: a mixture of two parts, by measure, of hydrogen with one of oxygen explodes on the application of flame, with extraordinary violence, and water alone results. I have here a soda-water bottle, which has been filled over the pneumatic-trough with the two gases mixed in proper proportions, and corked while under water. I wrap a towel round the bottle to guard against an injury in case of its breaking, and now, drawing a cork, I apply a lighted taper. The mixed gas, you hear, explodes with great violence, and water is formed; but this is hardly a fair experiment, for the bottle, not long since, was standing over the water in the pneumatic-trough,—therefore, the moisture which now bedews its internal surface may either be water which has formed by the combination of the two gases, or water which it has acquired from the trough. However, I have succeeded in proving one fact, that a mixture of hydrogen and oxygen gases explodes on the application of flame. In order to prove that the result of the explosion is water, and nothing but water, an expensive instrument is required, which I will endeavour to describe by means of a diagram :—



The vessel, A, is made of very thick glass, and furnished with a stopper, S, which can be pressed tightly down by means of a screw. Into this stopper are inserted two wires, W W, one on either side, and which communicate with the interior of the apparatus. It is also furnished with a stop-cock, P. By means of the air-pump this glass vessel, A, is deprived of its atmospheric air, and it is afterwards filled with a known quantity of the mixed gas. The stop-cock, P, being then turned, and the stopper, S, being screwed tightly down, nothing can escape. But how is the gas to be inflamed without opening the vessel? The plan is simple enough: an electric spark, which resembles a flash of lightning in miniature, is passed, by means of the wires, directly through the gas, which consequently inflames, and water is deposited on the sides of the vessel. This experiment is quite satisfactory, for it may be proved that the weight of the water formed is precisely equal to the weight of the gases employed; and as the vessel is filled with gas without the aid of a pneumatic-trough, no fallacy can arise on this score.

Three-fourths of the globe on which we live are composed of water; and the great excess of this fluid has called forth from Delabeche, the geologist, the following remark—that the dry land of the earth can only be regarded as so many points, which, for the time being, are above the water, below which they may at some future period descend: or, in other words, if all the dry land of this world were made level, then would the water be sufficient to cover it quite over. Water is said to be without colour, taste, or smell; but this is an incorrect statement. Small quantities of water certainly do appear colourless, but in large masses it has a greenish hue, as may be seen in the ocean, also, to a less extent, in lakes and rivers. I think, too, that water possesses a taste; and as to its being without smell, the assertion may be true so far as human beings are concerned, but it is mentioned, on very good authority, that the camel, when travelling over the burning sands of eastern climes, will scent a spring of water although many miles away.

Pure water, then, is composed of hydrogen and oxygen; but naturally water cannot be found in a pure state. Sea-water contains common salt, besides many other substances; and spring or river-water, although much less impure than sea-water, is still far from pure. When I make use of this term pure, do not fancy for a moment that the water which we every day use is improper, or that purer water would better answer the purposes of domestic life; far from this, neither man, animals, birds, or fishes could exist if the earth were entirely supplied with water quite pure.

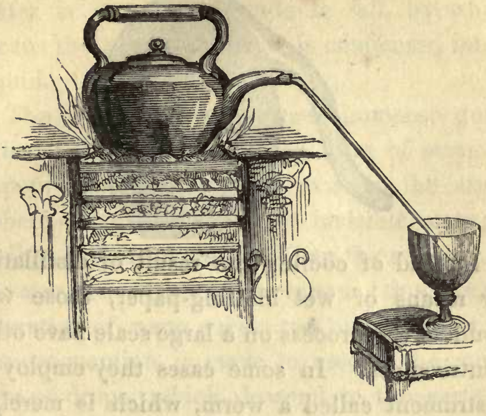
The purest kinds of water that exist naturally are melted snow and rain water, both of which are very insipid to drink. The chief impurities of water are atmospheric air and carbonate of lime, held in solution by carbonic-acid gas. I dare say you have often observed what a coating the tea-kettle acquires after having been used some considerable time; this coating or crust is nothing but chalk or carbonate of lime, which deposits as soon as the carbonic-acid gas which held it in solution, is dissipated by boiling. *All* gaseous substances are capable of being absorbed by water to a greater or less extent; you will have no difficulty, then, in comprehending how it is that water absorbs a greater quantity of the *atmosphere,* as well as of the gas which is always mixed with the atmosphere; I mean *carbonic acid.* The other impurities of water are collected from the earth through which it runs. By the process of boiling water is deprived of its atmospheric air, and rendered flat, disagreeable, and difficult of digestion. It appears, then, that atmospheric air is a necessary impurity; and those persons who drink boiled water under the impression that it is conducive to health, act in direct opposition to a wise provision of nature.

Fishes can no more live in boiled water than we can exist without air, for these creatures require air just as we do; only they breathe air which is dissolved in water, whilst we, and other terrestrial animals, breathe that which exists in a gaseous state. The gills of fishes are the representatives of lungs in land-animals, and just as gills can only perform the act of respiration in water, lungs can only perform the same act in the atmosphere. When water contains impurities of an unusual kind, and in large quantities, then it is termed mineral-water: the ocean may be called an enormous collection of mineral-water. Bath, Harrowgate, Tunbridge-wells, and Cheltenham are all celebrated for their mineral-waters.

By means of its tributary streams, the ocean has continually pouring into it large quantities of decaying substances, and without its saline ingredients it would speedily become a mass of putridity. The salts which it contains also increase its power of supporting weights, and hence render it better adapted for the purposes of navigation than it otherwise would have been. It is quite impossible to contemplate those facts and not be struck with the wisdom and the goodness displayed in that act of Providence, which made the ocean salt instead of fresh.

Whenever water is used for chemical purposes it must be pure, and common water is made so by distillation. Of course, you know that boiling-water gives off steam, and that this steam, if cooled sufficiently, becomes water again. Now let us refer to the circumstances of the encrusted tea-kettle. All the water which was in this kettle has by heat been converted into steam, or, in common language, has boiled away, and (mark what comes next) *has left the chalk behind.* Suppose, then, that instead of allowing the steam to fly away we had cooled it into water; why is it not evident that the resulting water would have been quite pure? The process of boiling would have driven off all its *gaseous* impurities, and chalk and every other *fixed* impurity would have remained behind.

If, then, you wish to obtain pure water, take a tea-kettle, and pour into it some common water, taking care that it do not rise so high as the internal surface of the spout. Now put on the cover of the kettle, and make it quite close with a little wet clay; this being done, fix into the spout a cork and glass tube thus.



On boiling the water in the kettle, it is quite clear that all the steam which arises must pass through the tube; which being cooled by the application of moistened pieces of blotting-paper, pure water trickles into the basin.

The operation you have been performing is called distillation, and I have directed you to employ a tea-kettle for mere simplicity.* Distillation may be conducted by retorts, by flasks and tubes, and by stills, which are instruments of this form :—

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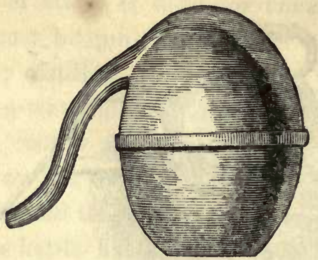
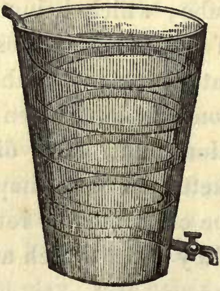
* After considering what has been here stated many other simple instances of distillation will present themselves to the reader.



Instead of cooling the result of distillation by means of wet blotting-paper, those who conduct the process on a large scale have other contrivances. In some cases they employ an instrument called a worm, which is merely a tube coiled many times round the inside of a tub filled with cold water in this manner.



At other times they use a receiver, precisely similar in appearance to a Florence flask, only much larger; on this receiver a stream of cold water is continually made to fall, by which means the vapour inside it is condensed into a liquid.

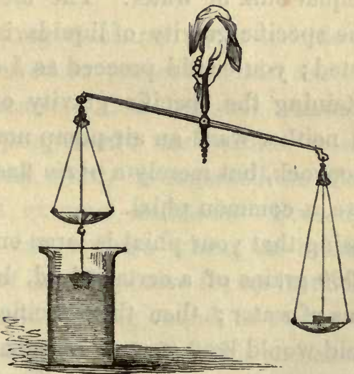
The heat of the sun causes immense quantities of water to rise in the form of steam or vapour: this vapour may exist in the atmosphere either in a visible or invisible state; if visible, it forms a cloud. When the atmosphere is saturated with visible vapour, this, by the operation of many causes too numerous for me here to mention, is made to assume the condition of drops, which descend to the earth in the form of rain. Snow is frozen watery vapour, and hail is frozen rain. Water from the clouds in either of those forms, after fertilizing the barren land, and covering the parched meadows with a carpet of green, sinks through little crevices in the earth, and appears to be lost: but soon it bursts forth in the form of bubbling springs, which roll down the sides of mountains and hills, to unite and form rivers in the valleys beneath. Those rivers, pursuing their course along the deepest levels of the earth, adorn, enrich, and fertilize the regions through which they pass. Some, gliding quietly on, seem made but to support the heavy ship; others seem created for terror alone, and descend in roaring cataracts from their mountain-beds; while the rivers of Devon dance over the mossy rocks, and sparkle in the sun, as if nature had not intended them to carry burdens, or to perfom any other hard labour, but merely to bathe the flowers on their banks, and to adorn the beautiful groves.

Water is the standard of specific gravity for fluids and solids, as I before told you. If we had to take the specific gravity of a solid, with whose exact size you were acquainted, such, for instance, as a piece of lead which had been cast into a pint measure, of course, we might compare its weight with that of a pint of water; but it would be useless to attempt proceeding in this manner with a substance whose exact size was unknown: let us suppose a shilling, for example; we could not take a sheet of water and carve it so that its size might exactly equal the size of a shilling; this would be impossible; and yet, before we can take its specific gravity, we *must* ascertain the weight of a quantity of water exactly equal to it in size; how then are we to proceed? That which cannot be effected by *direct* means, may sometimes be accomplished by those which are *indirect*, as you have already experienced in many of your chemical operations. The method of taking the specific gravity of solids is now known, and is therefore not difficult; but its discovery was only made by keen reasoning and deep reflection. There is a very pretty anecdote connected with this subject, which I will relate to you.

A king of Syracuse delivered to his goldsmith a certain weight of gold, for the purpose of having a crown made with it. The crown *was* made, and its weight equalled that of the gold delivered; but, nevertheless, the king believed it to contain some base metal, which was thought to have been substituted in place of the gold. How was this to be discovered? Gold was known to be heavier than any other metal, consequently a golden crown of a certain weight must necessarily be smaller than a crown of the same weight made of any other metal. But a crown is a very ornamental affair, covered with embellishments and carving; it would have been impossible to have measured every little inequality on its surface, and even supposing this accomplished, another crown of pure gold and of equal size, must have been constructed for the sake of comparison; in fact, the project would have been hopeless. What then could be done? The solution of the problem was entrusted to Archimedes, the celebrated philosopher of Syracuse, who attentively considered the subject, and obtained the necessary information in a very curious manner. One day, on entering a bath full of water, he found that some ran over; of course, any one might have remarked *that*. He also arrived at the conclusion that the quantity of water, by measure, which ran over must exactly equal the size of that part of his body which was immersed. Well, then, a golden crown of a certain weight must displace less water than a crown of base metal of the same weight, because it is smaller. Archimedes could wait no longer; his emotions overpowered him, and rushing naked from the bath into the streets of Syracuse, he ran wildly along, saying, "*I have found it! I have found it!*" and indeed so he *had;* for the king's crown was discovered to be larger than it ought to have been, from the fact of its displacing a greater quantity of water than an equal weight of gold was capable of doing.

The investigation of Archimedes did not cease here; pursuing his inquiries still further, he discovered that a body on being immersed in water, not only displaced a quantity equal to its own size, but that it was pressed up, and lost, for the time being, so much of its weight as was precisely equal to the weight of the water displaced. In this manner we can ascertain, by an indirect method the weight of a bulk of water, corresponding in size to any solid whatsoever, no matter how irregular in form.

I have here a piece of lead which I weigh in the air, and find its weight to be twenty-two grains; I now weigh it in water by means of this contrivance,



and its weight is only twenty grains; consequently the loss is two grains, and is exactly equal to the weight of that quantity of water which corresponds to the lead in size. By means of a simple rule-of-three sum, I obtain all the remaining information which is necessary.

Loss sustained by lead when weighed in water, or weight of so much water as equals it in size.		Weight of lead in air.		Water taken as one or unity.		Specific gravity of lead.
2	:	22	:	1	:	11

The specific gravity of lead, then, is eleven; that is to say, it is eleven times heavier than an equal bulk of water. The method of taking the specific gravity of liquids is not so complicated; you would proceed as I directed for ascertaining the specific gravity of gases, only you neither want an air-pump nor a flask with a stopcock, but merely a *plain* flask, or, if you please, a common phial.

Supposing that your phial is large enough to contain 900 grains of a certain fluid, but only 300 grains of water; then the specific gravity of the fluid would be 3, as may be seen by this rule-of-three sum:

300 : 900 :: 1 : 3

But even this calculation, trivial as it is, may be avoided, by means of an instrument called the thousand-grain bottle. It is a stoppered phial, which is known to be capable of exactly containing a thousand grains of water: now, suppose I fill it with a liquid of which it is capable of holding three thousand grains; without the aid of any calculation whatsoever, I should immediately know that the specific gravity of this liquid was three. So much, then, for specific gravities.

The long discourse about specific gravities was allowed to proceed amidst the most profound silence. Our Lecturer warmed as his subject progressed; and, gaining fresh energy with every word, he regarded the silence as a mark of extreme attention. Poor old man! imagine his surprise when, on breaking the thread of his discourse for an instant, to take breath, and looking round, he saw, or thought he saw, more than half of his audience asleep. Wiping the glasses of his spectacles, he took another glance, and was not deceived: more than half really were asleep. His mouth opened; his lips quivered; his eyebrows were arched, and a blush passed over his cheek. Scratching his ear with his little finger, he bore the appearance of one who was vexed at having spoken for a long time to little purpose. Slowly raising a ruler to the height of his nose, he let it fall on the table with a sharp tap, the sound of which in an instant aroused the sleeping philosophers, who, sitting erect, passed their fingers across their half-closed eyes, and by straining their lips over their teeth endeavoured to conceal those yawns which could not be suppressed. The old gentleman looked at them for a moment with an expression more sorrowful than angry; pushed his spectacles further on his nose; took a pinch of snuff; made a low bow; walked as far as the door; opened it; looked back, and said with a sarcastic, but not very ill-natured smile, "So much, then, for specific gravities!"

Had it not been that he was annoyed, I believe our instructor would have mentioned another compound of oxygen and hydrogen, called the *per*-oxide of hydrogen. It contains an equivalent or atom more of oxygen than water, and, like it, is a colourless liquid; but I do not think this peroxide of hydrogen has ever been made in England, nor has it been yet applied to any useful purpose, although well adapted for restoring the faded white of oil-paintings.

LECTURE XIII.

COMPOUNDS OF OXYGEN WITH CHLORINE—IODINE—BROMINE—CARBON, CARBONIC OXIDE, CARBONIC ACID.

OXYGEN unites with the simple substances chlorine, iodine, and bromine, in several proportions, to form various compounds, some of which are exceedingly dangerous, and none are of very great importance; I shall therefore omit their consideration, and pass on to the combinations of oxygen with carbon.

Oxygen and carbon unite in two different proportions, and form two different gases, which are called respectively carbonic oxide and carbonic acid. By inspecting this diagram you will see the relative quantity of oxygen and carbon in each.

	Parts by Weight.		Atoms.	
	Oxygen.	Carbon.	Oxygen.	Carbon.
Carbonic Oxide.	8	6	1	1
Carbonic Acid.	16	6	2	1

From which table it appears that the atomic weight of carbon is equal to six, and that of oxygen to eight. That carbonic oxide is composed of one atom of carbon united with *one* of oxygen; and carbonic acid of an equal quantity of carbon with *two* of oxygen. I shall only speak about carbonic acid, because carbonic oxide is neither a very common nor a very important substance.

All of you know, I dare say, how very dangerous it is to sit in close rooms where charcoal is undergoing combustion, because the surrounding air is rendered impure. The reason is this: charcoal, by the process of burning, unites with some oxygen from the atmosphere, and forms the very poisonous gas, carbonic acid, which contaminates the air. This is the same gas which also flies off from soda-water, champagne, and various other liquors, to all of which it imparts a peculiar freshness. Carbonic acid is also generated in large quantities by the breathing of animals. You see, then, that the burning of charcoal and the breathing of animals both generate the same poisonous gas.

It seems extraordinary to you, I dare say, that living creatures can manufacture, by breathing, a gas which contains carbon, or the matter of charcoal. To a chemist, however, the circumstance is by no means surprising: our bodies are in great measure made up of this carbon or matter of charcoal; a pound of dry flesh containing, at least, half-a-pound of it. Carbon, although necessary to the animal economy when in a certain proportion, becomes injurious if this quantity be exceeded. For the purpose of setting free this excess of carbon from the bodies of animals, nature has devised several processes; the most important of these is respiration, or the function of breathing.

Venous blood, or that which circulates in the veins, is rendered impure by the presence of carbon, or the matter of charcoal, which gives it a black colour, and renders it unfit for the purposes of life. This carbon, or charcoal, nature wishes to separate; and now remark the beautiful contrivance which she employs.

All animals have some provision for the purification of their blood by means of air. In man and the higher animals the scheme is as follows. There are placed in their chests two organs, called lungs, which in texture very much resemble a piece of sponge, and into which all the blood in the body is frequently forced, or squeezed by the contraction of the heart, just as water may be forced by the action of a syringe into a piece of sponge. By the act of inspiration, or drawing breath, air also enters the lungs, and its oxygen combining with the carbon of the impure blood, forms carbonic acid :—the same gas which is produced by the burning of charcoal.

We cannot reflect for an instant on this simple yet beautiful means of purifying the blood, without entertaining feelings of wonder and admiration, for the wisdom, goodness, and power of the Creator ; but the first outpourings of our gratitude and admiration are scarcely over, when we notice an apparent defect. If all breathing creatures are so continually generating a poison, the whole atmosphere must eventually become incapable of supporting life: we shall one day, perhaps, be suffocated—this carbonic acid will kill us: such, I say, are at first our fears ; but they are ungrounded. The Creator has devised a means for purifying the atmosphere, no less beautiful than that for purifying the blood ; it is this :—carbonic acid, although a poison to animals, is a nourishment to plants; the leaves of which having absorbed the gas, retain carbon, and set oxygen free in all its original purity. The leaves of plants, then, correspond in some measure to the lungs of animals; and not only in this, but in many other instances, we find in examining the functions of vegetables, those which correspond with functions of animals.

The atmosphere is poisoned by the act of respiration in two ways. In the first place, oxygen is removed from the atmosphere, to from a component of the noxious carbonic acid; and, secondly, nitrogen, itself a poisonous gas, is left behind in a separate state. There is this difference between the properties of carbonic acid and nitrogen gases. Carbonic acid is a positive poison, whereas nitrogen merely poisons by excluding oxygen. To be a little imaginative, then, let us suppose that each of those gases is a man, and a murderer. Carbonic acid lays violent hands upon his victim and kills him at once; but nitrogen starves *his* victim to death, by excluding all nourishment. This example illustrates the difference which exists between a positive and a negative poison. I must tell you, however, that carbonic acid is only a poison when breathed: we take a great deal of it into the stomach in soda-water, ginger-beer, champagne, ale, and cyder; not merely with impunity but with positive benefit. Carbonic acid exists in many substances as a solid; I may give as examples limestone, chalk, and marble, from which it may be driven off by the application of sufficient heat, when pure lime remains. This is, indeed, the usual method of preparing lime; and you will now experience no difficulty in understanding the reason why it is so dangerous to sleep near lime-kilns. I once remember the circumstance of a poor beggar boy who was killed in this manner: weary with travelling, cold, pennyless, and destitute, he approached a lime-kiln for the sake of its warmth, and laid himself down to sleep. Poor little fellow! he slept to wake no more; next morning he was discovered quite dead and stiff.

Carbonic-acid gas is also generated in large quantities during the fermentation of certain liquids. Brewers' vats, for instance, are very often full of it, and when in this condition, the person who might be unfortunate enough to enter one of them would, most certainly, lose his life.

Carbonic acid very often exists in pits or caves, both natural and artificial. You have heard, I dare say, of the celebrated Grotto

Del Cane, or Grotto of Dogs, near Naples, where dogs and other animals are killed merely to gratify the curiosity of travellers. It consists of an excavation in the side of a hill, and is represented by this drawing.

Into this excavation, carbonic acid pours through fissures or chinks in the rock, and covers the bottom of the grotto to the extent of three or four feet, but no more; for I should tell you that carbonic-acid gas is exceedingly heavy, and for that reason can never rise high enough to kill a man, although a poor dog, whose nose must remain below the deadly atmosphere, immediately falls down suffocated, and very soon dies, if he be not speedily thrown into water, which generally restores him. The guide who exhibits this grotto magnifies the wonder a great deal, by affirming that an animal which has been stupified in the grotto cannot be recovered by immersion in any other water but that of the lake hard by; however, if any of my young friends should in after times visit the Grotto of Dogs, they may perhaps remember that the guide's statement is false.

Most persons have heard of the dreadful Upas, or poison-tree, of Java, a tree that was reported to spring up quite alone in a valley, spreading death and desolation all around it, for a space of fifty miles; which was said to be covered with thousands of ghastly skeletons, sole remnants of its victims. This untrue statement was made by a Dutch traveller, named Foersch. It is undoubtedly true, that in Java there is a poisonous valley; and it is also true, that in Java there grows a poisonous tree, called Upas, but so far from its creating desolation and death for the space of many miles, the Upas is a tree which grows in the most fertile situations, and is surrounded by the most luxurious vegetation of an eastern clime. Twining plants creep round its stem—birds rest in its leafy branches—and beasts of prey come to sleep in its widely-spreading shade.

The poison-valley of Java has nothing to do with the Upas-tree at all. It is an excavation in the ground, about half-a-mile wide, and filled with carbonic-acid gas, just like the Grotto del Cane.

Foersch, after assuring us that all he is going to say shall be perfectly true, gives a detailed account of the manner in which the Upas poison is obtained: he tells us that criminals under sentence of death are permitted to choose whether they will suffer by the public executioner, or try their fortune in procuring some poison from the Upas. Of two evils they usually prefer the latter, as it affords them a slight chance of escaping. If fortunate enough to return with some poison, then all their crimes are forgiven, and they, moreover, obtain a reward.

"On the confines of the valley," says he, "there lives an old priest, whose duty it is to afford assistance, both spiritual and temporal, to such malefactors as are about to proceed on their generally fatal errand. At stated periods of the year bands of prisoners arrive at this old man's residence, and are there supplied with every requisite for performing their journey. The priest covers their heads with leather hoods, each having two glass eyes; supplies them with a silver or ivory poison-box; and then, ascending with them the summit of a hill, he gives directions for shaping their course, and, after commending their souls to the Almighty, he bids them farewell. They are directed to travel with the greatest speed, following the course of a little stream, which, at the distance of thirty miles from this point, flows close past the tree. If the wind at the commencement of their journey should blow in the direction of the Upas until the first thirty miles are travelled over, then they are usually safe; but if the wind should blow in their faces and waft towards them the deadly poison, they surely die."

Foersch afterwards proceeds to give a long account of an execution which he witnessed of fourteen of the emperor's wives, who were killed at one time by means of lancets poisoned with the juice of the Upas! He attributes the general unhealthiness of Java to the presence of this solitary tree, which not only kills by its poisonous emanations, but also affords every facility to secret murder, almost all the natives of quality carrying poisoned daggers or knives. He affirms that the Dutch inhabitants of Java never travel into any distant part of the island without taking with them fish, which they throw into water before presuming to drink it. If the fish live, all is well; if they die, the water has been poisoned. Finally, he relates an anecdote which, according to him, is current in Java, relative to the origin of the tree. It is represented that at one time the inhabitants of that part of the island, which is now desolate, were very sinful, and the prophet Mahomet caused the Upas to shoot up as a scourge to destroy them all.

One can hardly regret this fabulous account of the Upas-tree, seeing that it called forth a beautiful effusion from the late Dr. Darwin, who, in his poem called The Botanic Garden, or Loves of the Plants, thus describes it:—

"Where seas of gold with gay reflection smile,
Round the green coasts of Java's palmy isle,
A spacious plain extends its upland scene,
Rocks rise on rocks, and fountains gush between;
Soft zephyrs blow; eternal summers reign,
And showers prolific bless the soil in vain.
No spicy nutmeg scents the vernal gales,
Nor towering plantain shades the mid-day vales.
No grassy mantle hides the sable hills,
No flowering chaplet crowns the trickling rills,
Nor tufted moss nor leathery lichen creeps
In russet tapestry o'er the crumbling steeps.
No step retreating on the sand impressed,
Invites the visit of a second guest.

No refluent fin the unpeopled stream divides,
No revolant pinion cleaves the airy tides;
Nor handed moles, nor beaked worms return
That mining pass the irremeable bourne.
Fierce in dread silence on the blasted heath
Fell Upas sits—the hydra tree of death.
Lo! from one root the envenomed soil below
A thousand vegetative serpents grow.
In shining rays the scaly monster spreads
O'er ten square leagues his far diverging heads,
Or in the trunk entwists his tangled form,
Looks o'er the clouds, and hisses in the storm.
Steeped in fell poison as his sharp teeth part,
A thousand tongues in quick vibration dart.
Snatch the proud eagle towering o'er the heath,
Or pounce the lion as he stalks beneath,
Or strew as marshalled hosts contend in vain
With human skeletons the whitened plain.
Chained at his root, two scion demons dwell,
Breathe the faint hiss or try the shriller yell,
Rise fluttering in the air on callow wings,
And aim at insect prey their little stings.

Carbonic acid is very often found in wells, and would kill any person who might be rash enough to descend. This is a case in which you may with advantage exercise your chemical information. Carbonic acid, like nitrogen, does not support combustion; therefore it is prudent, before descending a pit or well, to lower down a lighted candle; if the flame should be extinguished, you would know for certain that the descent was dangerous: but I will tell you how to purify such a pit, so that a person may descend with perfect safety. Sprinkle some lime with water, and then let it be thrown down into the pit, after which you will find that the candle when lowered is no longer extinguished, because the lime has combined with the carbonic acid, and has become converted into a substance called *carbonate of lime.*

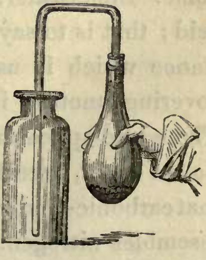
This remark brings me to the process for making carbonic acid: but you may say I have told you how to make it already—by the breathing of animals, by the burning of charcoal, and by the fermentation of beer: true, it may be made in those ways; but I am going to tell you a convenient process for making it; a process which yields it in the greatest abundance, and of the greatest purity.

I take a wine-bottle, furnished with a cork and bent tube; indeed the same apparatus as I used for the preparation of hydrogen. I now put into the bottle some white marble, broken into small pieces, (chalk would have done,) and pour upon it a mixture of oil-of-vitriol (called sulphuric acid) and water. I now replace the cork; wait till the first portions of gas have escaped, and then collect the remainder in the usual manner. While a bottle is filling, I will explain to you the theory of the decomposition: marble and chalk are both carbonate of lime; that is to say, they are composed of lime and carbonic acid united together. Sulphuric acid, on being added, takes away the lime, forming sulphate of lime, and carbonic acid escapes. The same decomposition is thus expressed by means of a diagram:—

Carbonate of Lime (Chalk.) { Carbonic Acid................*(escapes.)*
Lime

Sulphuric Acid————————————Sulphate of Lime.

The method which I have followed is the best for collecting carbonic acid; but if you do not want it exceedingly pure another plan may be followed, depending for its success on the fact, that carbonic acid is much heavier than atmospheric air. I shall not go through the process, but describe it to you by means of a sketch. You may ascertain when the bottle is full of gas, by dipping into it a piece of lighted wood, the fire of which will be extinguished immediately that it touches the gas.



We have now obtained

several bottles full of carbonic-acid gas, and will perform a few experiments with it. I take a pint wide-mouthed bottle, and place it without its stopper on the table: then taking a bent wire, supplied with a lighted taper, I fix it thus. Now I take a bottle filled with carbonic-acid gas, and pour it, just as I would a liquid, upon the lighted taper, the flame of which is immediately extinguished. This experiment has somewhat the appearance of magic, and would pass very well for a conjuring trick. It teaches us two things, that carbonic acid is much heavier than atmospheric air, and that it does not support combustion.

Into another bottle containing this gas, I pour some lime-water; which, having covered the mouth of the bottle with my hand, I shake briskly—see how white the lime-water has become. Lime-water, then, is a test for carbonic acid; that is to say, will discover it: one substance which is used for the purpose of discovering another is called by chemists a test. The white appearance is caused by the formation of chalk, or carbonate of lime. So it appears that carbonic-acid gas, in many of its properties, resembles nitrogen. Carbonic acid, however, whitens lime-water, which nitrogen does not.

Carbonic acid must exist as a solid in marble, chalk, limestone, and many other substances, although we usually obtain it in the form of gas: however, this gas, by the application of immense pressure, may be converted into a liquid, and this liquid has lately been frozen into a solid, but the process requires some costly apparatus, and is highly dangerous.

I have now said all that I consider to be necessary about carbonic acid, and in our next Lecture we will discuss the compounds of oxygen and sulphur.

LECTURE XIV.

COMPOUNDS OF OXYGEN WITH SULPHUR. HYPOSULPHUROUS ACID; SULPHUROUS ACID; HYPOSULPHURIC ACID; SULPHURIC ACID. COMPOUNDS OF OXYGEN WITH SELENIUM—PHOSPHORUS—BORON AND SILICON.

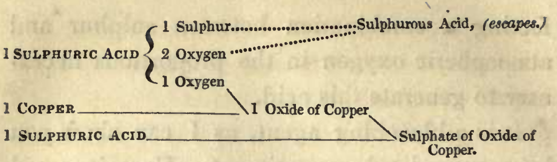
THE compositions of oxygen and sulphur unite in four different proportions to form four different compounds, which is represented by this diagram.

	Parts by Weight.		Atoms.	
	Oxygen.	Sulphur.	Oxygen.	Sulphur·
Hypo-sulphurous Acid	8	16	1	1
Sulphurous Acid	16	16	2	1
Hypo-sulphuric Acid	40	32	5	2
Sulphuric Acid	24	16	3	1

Of these I shall only mention the second and fourth. Most persons have noticed the disagreeable smell which is produced by a burning match; this depends upon the formation of sulphurous acid, which is evolved in the gaseous state; the process of combustion effecting a combination between sulphur and atmospheric oxygen in the proportions necessary to generate this acid.

It is a bleaching agent, as I can show you by a very simple experiment. Here is a red rose moistened with water, and at a little distance underneath it I hold a burning brimstone match. The red leaves of the rose very soon lose their colour, and change to white. It is by a process not very different to this that ladies' straw-bonnets are bleached, which, if it were not for this treatment, would be very far from white. Although sulphurous acid *may* be procured as I have described, yet when required in a pure condition another method must be followed.

Take a small glass retort; put into it some pieces of copper, or a little mercury, and then throw in enough strong oil-of-vitriol to cover the metal: afterwards apply the flame of a spirit-lamp, and sulphurous-acid gas comes over. By distilled water it is absorbed rapidly, but not by common water to an extent sufficient to prevent its being collected over a pneumatic-trough. Sulphurous acid neither burns nor is a supporter of combustion, as may be seen by lowering a lighted taper into a bottle full of it.



I shall now speak of sulphur*ic* acid, or oil-of-vitriol, which is a much more important compound. It is made by burning together a mixture of nitre (nitrate of potash) and sulphur, in such a manner that the results of combustion may be conveyed into a leaden chamber containing water. The exact nature of the changes which take place I shall not attempt to describe, knowing them to be too difficult for the comprehension of such young chemists as those around me. I may tell you, however, that by this process every sixteen parts by weight, or one atom of sulphur, is made to unite with twenty-four parts by weight, or three atoms of oxygen. Sulphuric acid in its pure state is a white crystalline body; but the sulphuric acid, or oil-of-vitriol of commerce, is a chemical compound of pure sulphuric acid and water. Uncombined sulphuric acid is usually an artificial compound, but it sometimes exists in the neighbourhood of volcanoes. Combined with other substances it is found in nature very largely:

Epsom salt is composed of sulphuric acid and magnesia, it is therefore called sulphate of magnesia. Glauber's salt is sulphate of soda; and plaster of Paris is sulphate of lime. Sulphuric acid powerfully reddens litmus-paper, and, whether alone or in combination, may be discovered by a very satisfactory test. Here is a wine-glass, containing some distilled water mixed with only one drop of oil-of-vitriol. I now pour in a little hydrochlorate of baryta: and, see! what a copious white precipitate immediately falls. Any other soluble preparation of baryta will do as well as the hydrochlorate. Many other white compounds are formed by solutions containing baryta, but none which possess the insolubility of sulphate of baryta: it may be collected and boiled in nitric acid without dissolving in the least degree, whereas all other white compounds formed by baryta are more or less soluble in nitric acid.

The changes which take place on adding hydrochlorate of baryta to sulphuric acid, are these. Sulphate of baryta is formed, and hydrochloric acid is set free.

I now vary the experiment a little, and add hydrochlorate of baryta, not to sulphuric acid, but to a substance containing it—Epsom salt;

still, you observe, the same white compound is thrown down.

The changes here are somewhat different. Sulphate of baryta is generated as in the former instance, but the hydrochloric acid is no sooner liberated than it unites with magnesia, forming hydrochlorate of magnesia.

Oxygen combines with selenium, and forms acids which are very similar to those of oxygen and sulphur, but they are comparatively little known.

Oxygen also unites with phosphorus in several proportions, to form different compounds, the principal of which is phosphoric acid. It never exists naturally, but when in combination with lime, forming phosphate of lime, it enters largely into the composition of the bones of animals.

Oxygen combines with boron in one proportion to form boracic acid. It never occurs as a natural product, but is obtained from borax, which is a borate of soda, or, to speak more correctly, a *bi*borate of soda; because there are two atoms of boracic acid combined with one of soda: *bis* or *bi* meaning *twice.*

Oxygen and silicon combine in one proportion, only forming silicic acid or silica. Under the less ostentatious name of flints, all of you have many times seen silicic acid.

I have already told you that flints are made up of an acid called silicic acid: true, it is not sour, nor does it redden litmus-paper, therefore two principal characteristics of an acid are absent; but it combines with bases and forms silicates, therefore chemists say that it is an acid.

I have not yet told you what a base is; you will best understand the meaning of the term by an example, which you shall have. Sulphuric acid combines with soda and forms sulphate of soda; with magnesia, and forms sulphate of magnesia; also with various other substances, each of which is called a base, and the combinations of acids with bases are termed salts. Just in the same manner silicic acid unites with soda, magnesia, and other substances to form silicates. Glass is a silicate of soda, and, chemically speaking, is a salt.

Do not mistake what I say; there *are* salts without any acid at all, of which class common sea-salt is an example, being composed of chlorine and the metal sodium; still the *greatest number of* salts are formed by the union of an acid with a base.

LECTURE XV.

COMPOUND OF NITROGEN WITH HYDROGEN— (AMMONIA) — WITH CHLORINE — IODINE — CARBON.

NITROGEN and hydrogen combine together, and form the substance called ammonia. Now, I dare say, my young friends are tolerably familiar with some of the properties of ammonia. They have doubtless seen and smelt the liquid called hartshorn. Ammonia is a colourless invisible gas, having a very strong odour; and hartshorn is nothing but a solution of ammonia in water.

Whenever animal substances are burned or exposed to a great heat, ammonia is generated: formerly the shavings of hartshorn were alone employed, and hence a solution of ammonia obtained that name: but ammonia of great purity cannot be obtained directly from this source; it is first necessary to make hydrochlorate of ammonia, and then to procure ammonia itself from this.

In order to make ammonia, I proceed as follows:—I take some lime, and sprinkle on it just enough water to make it crumble into powder. This powder is a compound of water and lime, called by chemists hydrate of lime. I now powder in a mortar some sal-ammoniac, (hydrochlorate, or muriate of ammonia,) which, by the way, is no very easy matter, and requires some little exertion. Having at length done it, I mix together in a mortar equal parts of this powdered sal-ammoniac and hydrate of lime; which mixture I immediately put into a stoppered retort, through the tubular or stopper opening. I now replace the stopper, and having put the beak of the retort under mercury,* I apply the heat of a spirit-lamp, which causes ammoniacal gas to be evolved in abundance. The first portions I allow to escape, of course, and the remainder I collect. As it is desirable to obtain the gas as dry as possible, you will remark that in the neck of the retort I have placed a roll of blotting-paper, which, of course, will absorb any moisture.

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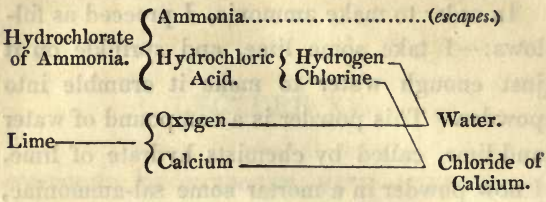
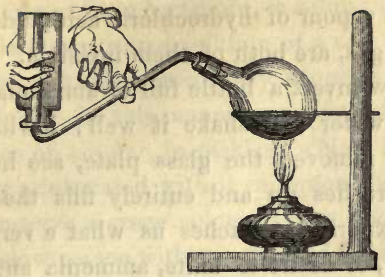
* It is difficult to get mercury so very pure that it will not soil the interior of a collecting-jar, therefore for all ordinary experiments the process of displacement is infinitely preferable.



Ammonia has such strong affinity or desire, so to speak, for water, that we cannot possibly collect it as we have other gases. Instead of water we must substitute the liquid metal quicksilver. In the shops are sold very strong pneumatic-troughs, generally made of cast-iron, and intended to contain mercury instead of water, for the purpose of collecting those gases which water would absorb.

Now we will employ, instead of mercurial-troughs, finger-glasses, and collect our gas in little bottles. Ammonia may be procured, however, tolerably pure without the aid of any mercury at all, by the process of displacement. This process I mentioned when speaking of carbonic acid; but ammonia is a much lighter gas than the atmosphere, therefore it cannot well be collected *downwards* like carbonic-acid, but *upwards*; thus:—



We have now several bottles which have been filled with ammoniacal gas by means of mercury; but they are so exceedingly small, that for the purposes of illustration I shall collect some fresh gas, by the less perfect, but more convenient process of displacement. Having arranged the apparatus, as represented by the diagram, I now commence the operation. The gas is invisible, therefore I cannot *see* when it overflows the bottle, yet I can smell it; or I can have recourse to a still more delicate and much prettier test.

I hold near its mouth a glass rod, which has been dipped in spirit of salt, (hydrochloric or muriatic acid,) and immediately the gas overflows, it unites with the acid, and causes white fumes, which are composed of little particles of sal-ammoniac. Here is an instance, then, of two invisible bodies uniting to form a solid;

for the vapour of hydrochloric acid and ammoniacal gas, are both of them invisible.

I now invert a bottle full of ammoniacal gas under water and shake it well; having previously removed the glass plate, see how the water rushes up and entirely fills the bottle. This experiment teaches us what a very great affinity, or desire to unite, ammonia and water evince for each other. We shall find, on examining this solution, that it has all the properties of hartshorn.

Into another bottle filled with this, I throw a bit of turmeric-paper, previously moistened with distilled water; and remark how very brown the paper becomes. This is a very important experiment: ammonia belongs to the class of substances termed alkalies, and all alkalies render turmeric-paper brown.

In a previous experiment I have already shown you that acids change the blue colour of litmus-paper to red. I now throw a bit of reddened litmus-paper into a bottle full of ammoniacal gas, and the original blue colour is immediately restored.

We shall require ammoniacal gas for a future experiment, therefore let us place a bottle full of it aside.

If I drop a little hartshorn, or solution of ammonia in water, into a solution of a salt of copper, the mixture immediately acquires a deep blue tinge; in this manner we may detect the presence of copper in pickles, which are frequently adulterated with it in order that they may preserve a green colour. How foolish to mix a slow poison with an article of food merely for the sake of imparting an agreeable colour!

With chlorine and iodine, nitrogen forms two most dangerous compounds; the slightest touch causes a violent explosion: once made, they cannot be handled, and a person is never safe when they are near. Monsieur Ampere, the discoverer of chloride of nitrogen, lost an eye and a hand in prosecuting his experiments on it; and two accidents by the same substance have come within my own personal observation. Under these circumstances I shall not teach you how to make either the chloride of nitrogen or the chloride of iodine.

Carbon and nitrogen unite to form a substance called cyanogen, from the Greek word *kuanos*, blue; because it enters into the composition of Prussian blue, which is composed of cyanogen and iron.

Cyanogen is also called the bicarburet of nitrogen, because its composition is two atoms of carbon and one of nitrogen. Cyanogen, when united to hydrogen forms that most deadly poison, named hydrocyanic,—or, because it is made from Prussian blue, Prussic acid.

LECTURE XVI.

COMPOUNDS OF HYDROGEN WITH CHLORINE— IODINE — BROMINE — FLUORINE — CARBON — SULPHUR—SELENIUM—PHOSPHORUS.

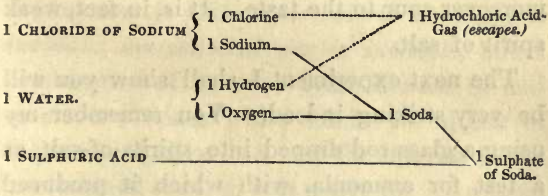
I SHALL now describe a very important compound: hydrochloric, or muriatic acid, a solution of which in water is commonly termed spirit of salt. Hydrochloric acid, as its name indicates, is a compound of hydrogen with chlorine, and in its natural state is a gas, some of which I presently intend making.

Hydrochloric-acid gas, like ammonia, cannot be collected over water; we must either employ a mercurial trough, or else have recourse to the process of displacement. The bottles used for collecting the gas in question should be perfectly dry: see with what scrupulous care I attend to this point: my bottles have been standing before the fire until they are quite warm, and now I wipe them out with a silk handkerchief, which, as they are large, I find no difficulty in doing, but I dare say it would puzzle you to dry a small-necked bottle, except you were shown the way.

Drying means the dissipation of a liquid in the form of steam, which dissipation cannot take place except there be a current, or draft: and in a bottle or other vessel possessing but one opening there cannot be a very powerful current. How, then, would you dry a small-necked bottle? I will tell you.

Having made it warm, insert a tube like this and suck out air from the bottle several times, by which means the moisture is also sucked out, and the bottle is dried. If this moisture be injurious of course you would take care that it might not get to your lungs, but you would perform suction by means of the mouth alone.

Not only have I dried the bottles, but I have likewise placed a roll of dry blotting paper into the neck of the retort, for the purpose of absorbing all moisture. It may be collected in the greatest purity by means of the mercurial trough; but although the process is very correct, yet it soils the bottles, and I shall therefore resort to displacement in preference. Into the beak of the retort I insert a bent tube, by means of a cork. Now, all matters being arranged, I pour upon the salt enough strong oil-of-vitriol to cover it: then I apply the heat of a spirit-lamp, and collect the gas which comes over.

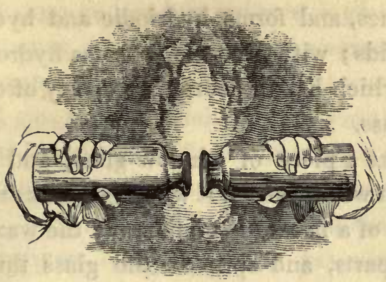


There is no difficulty in ascertaining when a bottle is filled, because the gas no sooner flows over, and comes into contact with atmospheric moisture than it forms dense white fumes. On observing this, I immediately close the bottle, by means of its own stopper, or a greased glass plate. Into one of our bottles I drop a slip of litmus-paper, and it immediately turns red; the result of this experiment demonstrates that the gas possesses acid properties.

Into another bottle I immerse a lighted taper, which is immediately extinguished, and the gas does not inflame. We learn, then, that it is neither a supporter of combustion nor a combustible.

Another bottle full of the gas I invert under water, when, on removing the stopper, the liquid rushes up with a violence almost amounting to an explosion: the bottle now contains a solution of the gas in water, which you observe reddens litmus-paper, like the gas itself, and is moreover sour to the taste. It is, in fact, weak spirit of salt.

The next experiment I shall show you will be very striking indeed. You remember my using a glass rod dipped into spirits-of-salt, as a test for ammonia, with which it produced white fumes: I will now show you those fumes in a more striking manner. In one hand I hold a bottle full of ammoniacal gas, and in the other hand a bottle full of hydrochloric-acid gas, both of which are covered by glass plates. I bring the mouths of the bottles together, and will trouble one of you to pull away the two plates.

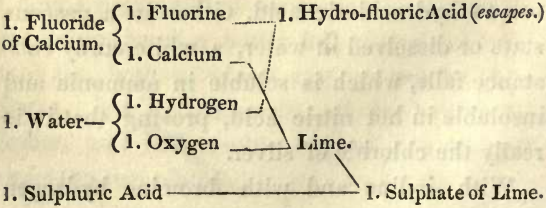


Now see the fumes, the whole room appears full of smoke: this, *indeed*, is a conjuring trick. I bring two apparently empty bottles together, and their mere approach fills the whole room with smoke. The explanation of the mystery is this: *hydrochloric acid* gas *is invisible, ammoniacal gas is invisible,* but a combination of the two, hydrochlorate of ammonia, is a dense white solid. As nitrate of the oxide of silver is a test for chlorine in the uncombined state, so is it a test for all soluble compounds which *contain* chlorine; therefore on adding a solution of nitrate of oxide of silver to hydrochloric acid, either in a gaseous state or dissolved in water, a white curdy substance falls, which is soluble in ammonia and insoluble in hot nitric acid, proving that it is really the chloride of silver.

With iodine and with bromine hydrogen

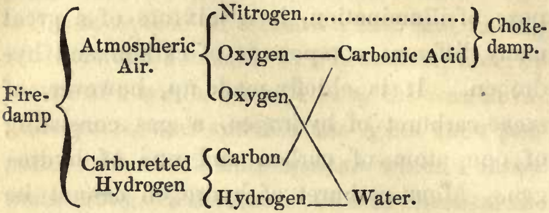
combines, and forms hydriodic and hydrobromic acids; with fluorine it forms hydrofluoric acid, which has the curious property of dissolving glass.

I take a piece of window-glass, and having made it warm I smear it with bees-wax; now, by means of a needle I scrape away the wax in various parts, and sprinkle the glass thus prepared with a little fluor-spar, on which I throw some strong oil-of-vitriol. Violent chemical action immediately takes place, on account of the production of hydrofluoric acid, which corrodes the glass, and renders it dull wherever the wax has been scraped away from its surface: in this way may be prepared very beautiful drawings. Now about the theory of the process: fluor-spar is composed of fluorine united to a metal named calcium, and is therefore called fluoride of calcium. Oil-of-vitriol is composed of sulphuric acid and water; a diagram will best explain the rest.



Hydrogen and carbon unite in a great many proportions, some of which are very curious and unusual.

Coal gas, now so much burned for the purpose of illumination, is a mixture of a great many different compounds of carbon and hydrogen. It is chiefly made up, however, of *mono*-carburet of hydrogen, a gas consisting of one atom of carbon and one of hydrogen. Mono-carburet of hydrogen cannot be made artificially, but it is evolved from stagnant water and the mud of ditches. Coal-mines sometimes furnish it in prodigious quantities, and when mixed with atmospheric air, it constitutes the terrific fire-damp so fatal to coal-miners. You remember my showing you that a mixture of hydrogen and atmospheric air is explosive; well, a mixture of carburetted hydrogen and atmospheric air is also explosive. Sometimes coal-mines are filled with this mixture, and you may form some idea of the consequences which result if it be set on fire. The dreary labarynths of the mine are filled with raging flames, accompanied by a sound like thunder; and the poor workmen are either shot into the air, as from a piece of artillery; or maimed, scorched, and bleeding, they only escape this calamity to be suffocated by the noxious gases which fill the mine after the explosion: these are called the choke-damp, the nature of which I can best describe to you by means of a diagram.



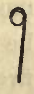
From an inspection of which it appears that the results from the explosion of fire-damp are water and two most poisonous gases—nitrogen and carbonic acid!

When sitting around your cheerful fires you little think amidst what dangers the fuel has been sought: you little think of the life which the poor miner leads. For the sake of a trifling pittance he shuts himself out from the light of heaven, and spends his days in the gloomy recesses of a coal-mine, where the fire-damp, brooding like a shadow of death, may in one minute launch him into eternity.

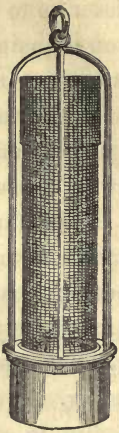
It was for the purpose of obviating those dangers in some degree, that the celebrated chemist, Sir Humphry Davy, constructed his safety lamp, the principle of which I will describe to you; but I must previously make you acquainted with the nature of flame. Flame is nothing more than burning gas; but in order to burn, it must possess a certain degree of heat; and if a sufficient portion of this heat be taken away, flame cannot exist.

I can illustrate what I mean by a common candle or taper; which, after all, is a gas-burner, but the gas is manufactured from the tallow immediately that it is required, whereas some gas-burners derive their supply from a gasometer.

But to return to my subject:—that I may illustrate the nature of the safety-lamp. I bend a piece of thick iron or brass wire into this form, and holding the ring part over the flame of a candle, I gradually lower it until it surrounds the wick, and in this manner I extinguish the flame; because the wire conducts or carries away heat with such rapidity as to cool the gaseous matter below the degree necessary for the existence of flame. I need scarcely inform you that the shape of the turn in the wire has nothing at all to do with its cooling effect, and that a square turn would answer as well as a round one. Now you are prepared to understand the construction of Sir



Humphry Davy's safety-lamp, which consists of a common lamp, surrounded with a cage of wire-gauze, every aperture through which has the same effect as our small iron ring. The fire-damp, then, *may* ignite inside the cage and fill it with flame, but this *cannot* pass through, at least while the lamp is still, or the explosive mixture not moving in currents.



The wire-gauze, it is true, may become red hot, yet even then it is much cooler than flame, and provided the lamp be kept *still*, and employed in atmospheres of fire-damp, which are also *still*, I believe no danger can occur. But I am convinced that the lamp is not proof against *currents* of fire-damp, which may at first render the wire-gauze red-hot by directing flames against it, and then make the flames pass through.

It is right for society to venerate distinguished men, and to award to them every praise which their merits may have earned; but in some cases this feeling is carried to excess. Divines, warriors, statesmen, poets, and natural philosophers; in short, all who stand out in high and bold relief from the general mass of society, at first experience difficulty in establishing a name; but no sooner is this name acquired,—no sooner has an individual wreathed his brows with laurels of his own fame, than the over-anxious and unjust populace bedecks them with stolen gems, and as mankind will enrich the gentleman who begs for a wager, while an object of charity is allowed to starve, so will they swell the long list of honours already belonging to some distinguished man, by denying to a more humble individual a credit which is justly his due.

We must not offer up truth as sacrifice to the memory of Davy: the shade of that truly great man would spurn the incense. His numerous masterly discoveries have conferred on him a fame which is imperishable; and his name, identified as it is with some of the sublimest philosophical truths, can never be mentioned but with respect. Wrong, then, as injustice must be under every circumstance, it becomes doubly so when perpetrated without even the shadow of a cause. I am not apprehensive of diminishing the fame of Sir Humphry Davy, by showing that one of his discoveries has been applied to practice with greater success by a working miner than it was originally by himself; and even if I were, I ought, nevertheless, to be just, and to state the undeniable fact, that there are circumstances under which the so-called safety-lamp of Sir Humphry Davy *is not safe*, and for reasons which I have already explained. The only safe modification of it that I am aware of was devised by a working miner, named Roberts, a person of great comprehension and natural abilities.

He has invented a lamp which I believe to be safe, whether surrounded by fire-damp at rest or in motion; and I cannot possibly divine the reason why it is not employed in our large coal-mines except that the name of Mr. Roberts, a miner, has not the weight which is attached to the name of Sir Humphry Davy. Still we must remember that Mr. Roberts has merely added something to the original discovery of Davy, and that to the latter philosopher (for I call both philosophers) we are indebted for some masterly experiments, by which he determined that small metallic apertures were an impediment to the passage of flame; a fact of the highest importance, for even the flame of the most explosive gas that exists, I mean a mixture of oxygen and hydrogen can be entirely arrested by means of several layers of wire-gauze.*

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* In the lamp of Sir H. Davy, the only safeguard against

Gas, which is employed for the purposes of illumination, is either made from coal or from oil, and consists, as I before mentioned, of several carburets of hydrogen mixed together.

Coal gas is made by exposing coal to a red heat in large iron retorts, by which means there are generated several carburets of hydrogen, tar, and sulphuretted hydrogen, all mixed together. The impure gas as it gets cold deposits its tar, and afterwards is freed from sulphuretted hydrogen by being passed through lime-water. It is now collected in immense vessels, called gasometers, and thence distributed in various directions through pipes.

The process for making oil gas is slightly different. Fish-oil is caused to drop gradually on a piece of red-hot iron, and by this means

an explosion is a single layer or envelope of wire-gauze; two layers, or even more, might be employed, it is true, but such an arrangement affords just as much impediment to light as to flame, and hence the instrument's utility is in great measure destroyed. The wick of Sir H. Davy's lamp obtains a supply of air from every part of the wire-gauze surrounding it, but Mr. Roberts causes the wick in his lamp to be supplied with air entirely from below, and this air can only arrive within the lamp by passing through many layers of wire-gauze. His lamp, then, may be described as a common safety-lamp, perforated in the bottom, screwed upon a brass box, which is filled with wire-gauze, and surrounded with a cylinder of glass.

it is immediately converted into gas, which passes into proper gasometers.

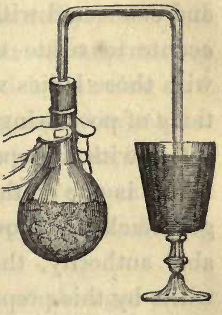
Hydrogen and sulphur unite in two proportions, forming sulphuretted hydrogen, also called hydrosulphuric acid and persulphuretted hydrogen.

Sulphuretted hydrogen, or hydrosulphuric acid, is a gas which is plentifully evolved from the earth in volcanic regions, and in smaller quantities from decaying animal matters; it also is a constituent of certain mineral waters. Sulphuretted hydrogen is a very disagreeable, but nevertheless a very useful gas.

The importance of sulphuretted hydrogen induces me to show you how to prepare it; but the process, if you please, shall be gone through in the open air. It is a most valuable test for metals, and for the purpose of illustrating this property, I must trouble you with its disagreeable smell.

Now metals are not soluble in water. I might keep a sixpence immersed in water for any length of time without dissolving the least particle of it; but if I add to the water a little nitric acid, then the silver will be dissolved. I shall speak of this more fully by and by; all I wish you to recollect at present, is that metals *can* be dissolved.

I have before me four different solutions containing four different metals, lead, arsenic, antimony, and zinc; through these I will pass a current of hydrosulphuric acid gas; but first let me make it. Into a Florence flask I put about half an ounce of a substance called sulphuret of iron, and over this I pour a mixture of six parts of oil-of-vitriol and one of water.

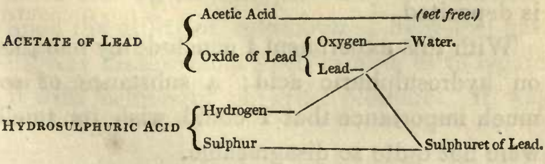


Now I fix into the mouth of the flask a cork furnished with a bent tube, through which the gas passes in abundance. First I dip the tube into the solution of lead, and see how black it turns. I now dip it into the solution of arsenic, which becoms yellow; into that of antimony, and a red colour is produced; into the zinc solution, and the colour is white. Now with many metals besides lead will this gas produce a black colour, but I could distinguish them one from another by various tests. I know, however, that there are only three metals which produce a yellow colour with the gas, and but one that yields a white; while antimony is the only metal that furnishes a red colour. If I pass a stream of hydrosulphuric acid gas through water, a great deal is absorbed, and there is obtained a solution which is very often advantageously employed as a test for metals instead of the gas itself. Hydrosulphuric acid gas enters into the composition of certain mineral waters; Harrowgate water, for instance, contains a large quantity of it; and connected with this subject, I have an anecdote to relate to you. It *was* a practice with those ladies who were particularly ambitious of possessing a white skin, to daub themselves with a preparation of the metal bismuth, which is one of these that sulphuretted hydrogen blackens. Now it is represented on creditable authority, that a lady made beautifully white by this preparation, took a bath in the Harrowgate waters, when her fair skin changed in an instant to the most jetty black. You may judge how much was her surprise at this unlooked-for change; uttering a shriek, she is reported to have swooned; and her attendants, on viewing the extraordinary change, almost swooned too, but their fears in some measure subsided on observing that the blackness of the skin could be removed by soap and water. The lady soon recovered from her trance, and derived some consolation from having the true state of things explained to her by her physician, although she was not very well pleased that people should have discovered the philosophy of her white skin.

If any ladies continue to use this preparation, I would advise them to take particular care that they do not sit too near a coal fire, for their features would assuredly grow dark and dusky, from the action of sulphuretted hydrogen, which is produced by burning coal. Solutions of lead, then, are blackened by sulphuretted hydrogen, and this metal enters into the composition of white paint; hence we account for the dark colour of mantel-pieces which were originally painted white.

The theory of the action of this gas when passed through metallic solutions, is very simple.

Suppose we refer to the lead solution; that which I used contained acetate of the oxide of lead. On passing through it a stream of hydrosulphuric acid gas, the changes which ensued are represented by this diagram.



From which it appears that acetic acid is set free, water is formed, and black sulphuret of lead is thrown down, or, as chemists say, is *precipitated.* I have already remarked, that metals in an uncombined state are not soluble in water, they must be in combination. If we form a precipitate by passing hydrosulphuric acid through a metallic solution, this precipitate is a combination of the metal with sulphur, and is called a *sulphuret.*

I shall now show you two more experiments with hydrosulphuric acid, and then close the subject. Into a bottle full of the gas I lower a lighted candle, which is immediately extinguished, although the gas itself burns and deposits sulphur. By this experiment I prove it to be a combustible, although not a supporter of combustion.

I have here another bottle full of it, which corresponds in size to a bottle full of chlorine. Now I bring the mouths of them both together, and see what takes place—the two colourless gases react violently on each other, and sulphur is deposited.

With this experiment I conclude my remarks on hydrosulphuric acid; a substance of so much importance that I could wish its smell were not quite so disagreeable.

Hydrogen and selenium unite to form a gas which resembles in many of its properties hydrosulphuric acid. Hydrogen and phosphorus unite in two proportions, forming two different gases: one called the *proto*-phosphuret, and the other the *per*-phosphuret of hydrogen. I shall only notice the latter, which can be made in various ways; but it may be best prepared by throwing pieces of a substance termed phosphuret of lime, into a mixture of water and hydrochloric acid, when phospuretted hydrogen gas is evolved in bubbles, and bursts into flame immediately on coming into contact with the air. The Will-o'-the-wisp, or Jack-o'-lantern, which is sometimes observed in the neighbourhood of burying-grounds may probably be nothing but perphosphuretted hydrogen gas, evolved from the bodies underground.

I must confess that notwithstanding all the eulogiums which were passed by our instructor upon the utility of sulphuretted hydrogen gas, its very disagreeable smell caused us to regard it with feelings of no great pleasure. It was not to be expected that we could avoid breathing some of it, although we did our best endeavours to prevent this, and every project that our ingenuity could devise was resorted to without effect: the gas *would* get down our throats, and so indeed it *did*.

It was about five o'clock in the afternoon of a beautiful May day when the Lecture terminated. The birds sang merrily in the budding trees, and the sweet odour of the wild hedge-flowers afforded a pleasing contrast to the smells which we had been enduring. I do not know whether our Lecturer had been heard with less attention than usual, or whether he saw depicted on our features any signs of disgust or dislike to the studies in which we had been engaged; but I have reason to believe that we all looked very unamiable, and that such was observed to be the case by the good old man. Anxious as he always was to afford us rational amusement, and fearful lest our fondness for philosophy might suffer some diminution, his anxiety on this occasion was greater than I ever observed it before. Puffing and sneezing, holding our noses, and making wry faces, we were walking sullenly towards our homes, when our good-natured old friend, tapping us play-fully on our heads with his walking-cane, proposed a walk in the fields, telling us that he would relate a funny tale about this sulphuretted hydrogen gas. The walk was agreed on, and the tale was told: I will relate it as near as possible in the old man's words.

A TALE

ABOUT A GIANT AND A DWARF.

Of all the merry-makings which it has been my lot to see, none has ever pleased me so much as a village fair. The Lord Mayor of London's show, the King's visit to parliament, and all other fine sights put together, never afforded me half the gratification that I have felt from being present at a country fair. But my recollections of *all* country fairs are not pleasant, as will appear in the course of the tale which I shall presently relate; although I am convinced that the chastisement which I then suffered for an act of wanton mischief taught me a useful lesson for my guidance in after life. It taught me in a practical manner something which I had heard theoretically advanced many times before: that knowledge is power, either for good or for evil, and is only conducive to happiness when enlisted on the side of virtue.

In the early part of June, some sixty years ago, I was present at the annual fair of my village. I was then about ten years old. The approach of the fair-day was a subject of pleasurable anticipation for every one within a dozen miles of the place: the village cottages were whitewashed; the rose-tress were pruned; the garden-walks were nicely weeded, and brushed clean from leaves; the cottage-doors were painted; and, in short, every thing was done that could make our homes more comfortable or more neat; for the fair-day was one of hospitality to all strangers; and to have received them in negligence or untidiness would have seemed to us the height of ill-breeding. It was a pleasing sight for us boys, when perched upon the cottage-roofs, or seated on the bough of some tall tree, to watch the busy preparations which were making for the approaching festivities. Some were employed in partitioning off the village-green into square divisions for the cattle: some were erecting booths for sweetmeats and toys, and some were fixing swings and round-abouts; while in another part of the green the village authorities were in earnest conversation with mountebanks, showmen, conjurers, and fruit-sellers, respecting the price which each should pay for a certain space of ground. No statesmen, settling a treaty between nations—no warriors, inspecting the field of an approaching battle, could look more serious and sedate than these: if their very lives had depended on the termination of the conference they could not have looked more grave. The heads of some were moving from side to side; the heads of others were moving up and down; some grasped their pockets convulsively, and turned on their heels; some curled their lips and counted their fingers: in short, a careful observer, placed far enough away to be out of hearing, but still within sight, might have seen depicted in their ever-changing gestures, all those varieties of feeling which are manifested in the course of mercantile transactions of the most extensive kind.

Far beyond this busy scene the horizon was clouded with rising dust, caused by the approaching cattle and caravans. In a short time they were distinctly visible, and in the space of a few minutes more we saw them descend the hill immediately opposite to their place of destination. The cattle galloped and frolicked as if they too enjoyed the approaching festivities; and so perhaps they did, for none of them were tired from long travelling, having merely come from adjoining farms; and if they could be pleased with their own fine appearance, and experience a little of human vanity in being gazed on and admired, they must have felt pleasure indeed: be this so or not, they *did* appear pleased; why I cannot tell. Now came donkies, with gingerbread, fruits, and toys; carts, with mountebank-stages, balancing-poles, swings, and round-abouts; then followed caravans with wild beasts, penny-peeps, giants, and dwarfs; next the more humble punchinellos, dog-cart men, and blind fiddlers; who, having allowed the aristocracy of the craft to advance before, now followed in the rear. The bells all the time continued ringing merrily, and thus passed away the evening.

Now I must suppose the night spent; not in sleep, at least, by me, for I was too anxious; however it *was* spent, and the fair-day had arrived, which brings me to the subject of my tale. I am sorry to own that when young I employed my little stock of scientific knowledge chiefly in playing practical jokes, and this propensity did not entirely leave me until the fair-day, which I am now about to describe. Scarcely waiting to finish my breakfast, I sallied out with some of my young friends in search of adventures, and passing along a row of show-caravans, I was struck with the appearance of a picture, representing a giant and a dwarf, who were to be seen inside, together with a boa-constrictor and an alligator, all for the sum of one penny. Attracted by the harmony of a kettle-drum and cracked trumpet, a larger crowd of spectators surrounded this caravan than any other; and the managers were enjoying in consequence an undue monopoly. The wild beasts' men in vain bawled forth the names and nations of their wonderful animals. Punchinello jabbered to the empty air, and the mountebanks danced and grimaced in vain; the giant, dwarf, alligator, and boa-constrictor were all the rage; and the trumpet and kettle-drum drew wondering crowds into the caravan. "I have sartinly seed many a bigger fellow than he," said a countryman, stepping out. "If I beant mistaken," continued another, "the feller is on stilts, and if a body could make un come out upon the ground and show his inches fair and undeceitfully, he would look a wonderful different man." I do not know how it was, but this conversation aroused in me the most pleasurable sensations: I reasoned myself into a belief, that if there was any deceit in the matter, I should act properly in exposing it, by exhibiting the giant in his full proportions. When the mind is bent upon the performance of some mischievous trick, we first quiet conscience by endeavouring to clothe our evil propensities in a garb of virtue;—so was it with me; I fancied that by drawing the giant out I should exhibit any deceit that there might be; and if there should be no deceit, then the giant might walk in again. But my conscience was not quite satisfied upon this point, inasmuch as the dwarf too must certainly experience some inconvenience if my proposed measure should be carried into execution:—perhaps also the alligator and snake might suffer. However, I had determined that the giant *should* come out, and conscience in vain whispered—no.

Returning home, I selected a basin, provided myself with ingredients for making this disgusting sulphuretted hydrogen, and filling the basin with nuts, the better to disguise my schemes, I crept stealthily under the giant's caravan, where, having set on the preparation of my gas, I retreated as fast as I could, allowing the noxious stench to ascend through the cracked and separated flooring of the caravan. Standing at a little distance on a hillock, I watched the result. "*Walk in, ladies and gentlemen*," bawled the conductor; "*squeak*" went the trumpet, "*bang*" went the kettle-drum; but all in vain, the ladies and gentlemen kept walking out instead of walking in; their faces contorted and their noses compressed. Presently the musicians too left their posts, for the stench was intolerable. Another moment, and the ground was cleared for the space of many yards around the caravan; that is to say, all had left it but myself, who, standing on the little hillock, was enjoying a sight of the mischief which I had created. Whilst I was one of the crowd, my ecstacies, for aught I know, might have remained unnoticed; but standing alone they must necessarily have been remarked, and, indeed, so they were. Presently the dwarf gave a convulsive shriek—the giant roared aloud, and bursting from the caravan with the dwarf clinging tightly round his neck, he jumped from the platform to the ground, where heaving his great chest, and staring wildly around, he looked like an infuriate being from another world. Whether irritated by my laughter, or guided by an instinctive sense to the person of his tormentor, I know not, but leaping towards the hillock on which I stood, he snatched me in an instant from the ground.

I now repented of my joke, for he clawed and shook me about as a cat does a mouse;—a sound drubbing I would not have cared so much about, but the monster almost strangled me;—his great hands squeezed me so that I thought every bone in my body was broken. Cry I could not, for he closed my mouth by main force, in order that I might be tortured with greater effect. He did not strike me, it is true; if he had I think I must have died; and in this forbearance he was generous, well knowing his own immense strength; but having clawed me for a minute or two, he very coolly held me under one arm, my head towards the ground, and my feet kicking aloft; while the dwarf on his shoulder was busily engaged in belabouring my back and sides with a cudgel; a task which he executed with great perseverance and effect, exerting at every blow his utmost strength; *he* not being at all afraid of breaking my bones. Even this treatment was a relief to me, because I could cry. The people were panic-struck, and what with the horrible smell, and what with fear of the giant, no one came to my assistance; indeed I did not deserve that they should. How the rest of the day passed I know only from hearsay: feverish and delirious I found myself two days afterwards in bed, surrounded by two doctors and a nurse. Six weeks passed, and I was yet unable to walk from the effects of my squeezes and bruises: however, I suffered no lasting injury, and I have many times since then been thankful that my fondness for practical joking experienced such a timely and salutary check.

From what I have been told, the giant really looked as large outside the caravan as he did inside it, and he did not require the aid of stilts to increase his height. As to his strength I can offer personal testimony. But the sun has set, and I have reached my abode, therefore good night to you all.

LECTURE XVII.

METALS.

HAVING finished the description of non-metallic simple bodies, and the compounds which they form with each other, we now have to say a little about those which are metallic or metals. Ah! there cannot be very much to remark concerning them, think you; gold, silver, iron, tin, lead, and a few others will finish the list. No, no, the metals are not so soon done with; there being no fewer than forty-one* of them, although perhaps you are not familiar with more than nine or ten. The ancients were only acquainted with seven. But what is a metal? how shall we discover whether a substance be metallic or non-metallic? This question has puzzled many greater philosophers than ourselves, and is not yet quite made out. We usually associate with the term metal ideas of shining and very great weight; but there are some which neither shine when polished, nor sink when thrown into water. Metals are fused or melted with greater or less difficulty, the common temperature of the atmosphere being sufficient to melt quicksilver, while the metal platinum cannot be fused by the strongest heat of a furnace, although the action of a galvanic battery melts it like wax in the flame of a candle: so also does the little flame of an oxy-hydrogen blowpipe. By the bye, I must describe to you the nature of a blowpipe. In performing operations which require a high degree of heat, manufacturers on the large scale are obliged to have recourse to furnaces; but philosophic chemists who operate on smaller quantities very often dispense with furnaces altogether, and employ as a substitute the flame of a common candle. You are incredulous, I see, but I must tell you the heat of the flame is increased to an enormous extent, by means of an instrument called the blowpipe, which is a bent metallic tube, terminating in a very fine jet.

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* It has already been mentioned that the substance in these Lectures termed silicon is regarded by some persons as a metal, and termed by them silicium, in which case the number of the metals would be forty-two.

It is used for the purpose of blowing the flame of a candle upon any substance which one may require to be exposed to a high degree of heat, either for the purpose of melting or otherwise. When a very large flame is required a lamp with a large wick must be substituted for a candle, and a pair of double bellows for the mouth. Of this description is the blowpipe used by those who work in glass.

If the heat be required exceedingly violent, then an instrument called the oxy-hydrogen blowpipe is employed, which is a contrivance for burning with safety a mixture of oxygen and hydrogen gases. This mixture would explode violently were it not for a very ingenious expedient founded on the principle of Davy's safety lamp. If one layer of wire gauze be sufficient to intercept the flame of a gas, no more explosive than fire-damp, then it is but reasonable to infer that a greater number of layers would be able to intercept the flame of a much more explosive gas.

This is the principle of the oxy-hydrogen blowpipe; the mixed gas being forced through a great number of layers of wire gauze,—beyond which the flame cannot pass. Instead of wire gauze, there is now employed another and a better substitute; but its principle of action is exactly similar to that of the wire gauze.

Well, this description of blowpipes is a slight digression: let us return again to our subject.

Some metals by fusion may be made to unite together, and form a compound dissimilar in properties to either of its constituents: such compounds are termed alloys; but the union of mercury with any other metal is termed an amalgam. Brass is an alloy of copper and zinc; bell-metal of copper and tin; and pewter of tin and lead. The metals are all of them, so far as is known, simple, or undecomposable substances, therefore, however much they may be altered in appearance by combination with other substances, still it is impossible to change one metal into another, and therefore the transmutation of common metals into gold is beyond all human power. If the alchemists had arrived at this conclusion they might have saved themselves much fruitless labour and anxiety.

Some metals can be beaten out into thin leaves, and hence are called malleable; *malleus* being the Latin word for hammer. A single grain of gold may be made, by hammering, large enough to cover a space of fifty square inches; or in other words, would be quite sufficient to gild a large tea-table. Some metals are brittle, like antimony: others, can be drawn into wires, and hence are said to be ductile. From a consideration of these properties, metals may be divided into a great number of classes; but the most modern classification of metals is formed from a consideration of their chemical pecularities. I shall follow the historical arrangement, and speak of metals in the order of their discovery.

Although there are now known no less than forty-one metals, yet the ancient Greeks and Romans were only acquainted with seven; gold, silver, mercury, copper, lead, tin, and iron.

Metals for the most part are obtained from under the surface of the earth, and here we cannot fail to be struck with a beautiful provision of nature; if instead of under the earth, great masses of metal had been placed on its surface, then there could not have been any beautiful green fields, but all now so lovely, would have then been barren and desolate.

No metals, when in a pure state, can be dissolved by water; but all of them form soluble compounds, in which the metals are capable of being discovered by appropriate tests.

NAMES OF THE METALS.

Gold,
Silver,
Iron,
Copper,
Mercury,
Lead,

Tin,
Antimony,
Zinc,
Bismuth,
Arsenic,
Cobalt,
Platinum,
Nickel,
Manganese,
Tungsten,
Tellurium,
Molybdenum,
Uranium,
Titanium,
Chromium,
Columbium,
Palladium,
Rhodium,
Iridium,
Osmium,
Cerium,
Potassium,
Sodium,
Barium,
Strontium,
Calcium,
Cadmium,
Lithium,
Zirconium,
Aluminium,
Glucinium,
Yttrium,
Thorium,
Magnesium,
Vanadium.

Gold.—Gold seems to have been known from the most remote ages, and at this circumstance we cannot be much surprised; for unlike most other metals which are generally dug from the earth in an impure state, gold more generally occurs quite pure, and fit for working. In many regions it is found either on the surface of the earth or at a very inconsiderable distance below it. Unskilful nations, then, who had not learned the method of extracting metals from their ores, might yet be struck with the appearance of shining gold, which they could, without much difficulty, beat or melt into various useful or ornamental shapes. There are few countries which have not at some period or another yielded gold; the greatest quantity of the metal, however, is brought from South America and Africa, but Hungary, Sweden, and Norway yield it in smaller quantities, nor must we forget our own isles. In Cornwall there have very frequently been found small grains of gold, to a very considerable extent; but in Ireland, in the county of Wicklow, there were formerly worked gold *mines*, and gold was once found so abundant in Scotland; that at the nuptials of James the Fifth, covered dishes filled with Scotch gold were presented to the guests by way of dessert.

Near Pamplona in South America, single labourers have collected upwards of two hundred pounds worth of gold grains in a day, and in the province of Sonora, the Spaniards discovered a plain fourteen leagues in extent, in which they found gold-wash at a depth of only sixteen inches. The grains were of such a size that some of them weighed seventy-two ounces, and in a very short time a few labourers had collected so much gold as was equal in value to more than thirty-one thousand pounds of our money.

Gold never rusts or combines with oxygen by exposure to air, and hence it is admirably adapted for the purpose of making coins. It may however be made to combine with oxygen by an artificial process, and the result is oxide of gold. Although this metal does not rust or tarnish by exposure to the air, yet by an artificial process it may be made to combine with oxygen in three proportions, also with chlorine, iodine, and sulphur. It was this indestructibility of gold which induced the alchemists to employ it as an ingredient of the universal elixir, by the administration of which they hoped to render man immortal. If gold be indestructible, thought they, we can eat and drink enough of it to become indestructible ourselves: but the alchemists were wrong, as they in due time discovered.

SILVER.—This is a beautiful white metal, too well known to require a minute description. It is obtained from South America, Hungary, and various other parts of the world; not to mention our own isles, where it is found in combination with lead. Silver, like gold, is incapable of rusting or tarnishing by exposure to the air, and hence is well adapted for the purposes of current coins; but the Romans did not employ silver for this purpose until the four hundred and eighty-fifth year of their city, up to which period they only used copper. When quite pure, silver is so soft that it may be cut with a knife; and it cannot be used for the purposes of coining or jewellery, until it has been mixed, or alloyed, with a certain quantity of some other metal. English silver coins contain a small portion of copper.

Although silver is not capable of rusting or oxidation by mere exposure to the air, yet by artificial means it may be made to combine with oxygen, chlorine, iodine, bromine, and sulphur.

MERCURY OR QUICKSILVER.—This is a very curious metal, being always liquid at common temperatures; although by intense cold it may be frozen, and when solidified it is malleable. In the neighbourhood of Hudson's Bay, this metal has been beaten out into leaves as thin as paper. The term mercury was applied to quicksilver by the alchemists, who called it after the winged messenger of the gods, because of the ease with which it is driven into vapour, or volatilised by the application of heat.

There are some metals with which mercury is very prone to unite, and the combination of the two is termed an amalgam. If I rub a little mercury upon a sixpence, the latter assumes a glaring white aspect, and feels as if it were smeared with oil. Very slight force would now be sufficient to break it in pieces; but if I heat it in the flame of a spirit-lamp, fumes of mercury are seen to arise, and the sixpence is restored to its original condition.

This property of mercury is taken advantage of in the silver-mines of South America and Hungary. The ore as it comes from the mine is mixed with mercury, which combines with the silver alone, and leaves the impurities behind. An amalgam of silver is thus formed, from which the mercury is obtained by distillation, and the silver obtained quite pure.

Mercury is found in Peru, the East Indies, Almaden in Spain, and Idria in Lower Austria; also in Hungary, Sweden, and China. Spain furnished mercury so abundantly, that in the year 1717 there remained above one thousand two hundred tons of it in the magazines of Almaden, after the necessary quantity had been exported to Peru for the purpose of extracting silver from the ore. But Peru yields quicksilver of its own; its largest mine being that of Guanca Velica, which is one hundred and seventy fathoms in circumference, and no less than four hundred and eighty deep. In this immense cavity are houses, streets, and even a chapel for the performance of religious ceremonies. The miners are chiefly criminals, who, immured naked in this dreary abode, very soon die of the most horrible convulsions.

Mercury combined with sulphur, as a sulphuret of mercury, called cinnabar, is found as a natural product; by artificial means the metal may also be made to combine with oxygen, chlorine, iodine, bromine, and cyanogen. The substance called calomel, and so much used in medicine, is a *bi*chloride of mercury, or a compound of two atoms chlorine, with one of the metal.

Copper.—Copper is a metal of a reddish colour, too well known to require a minute description. The ancient Greeks and Romans were well acquainted with it, and applied it to many uses for which we now employ iron. The most ancient copper-mines were in the isle of Cyprus, and it is now found in North America, Sweden, China, Japan, Sumatra, North of Africa, also in Cornwall, and the Isle of Anglesea, in England. English copper-mines have not been worked more than one hundred and sixty or one hundred and seventy years;

before that period, whenever the workmen met with copper they threw it away as useless. So very cheap is copper in Sweden, that houses are covered with it,—as indeed is the London Coliseum in the Regent's Park.

Immense quantities of sheet-copper are used in our dock-yards for the purpose of sheathing the bottoms of ships, in order to protect them from the action of sea-water. All copper vessels, which are used for the purpose of preparing food, should be kept remarkably clean and bright, because acid and fatty substances dissolve the metal, and generate a most dangerous poison.

Solutions containing copper strike a blue colour with hartshorn, or solution of ammonia, and by this test the metal in solution may always be discovered.

Copper unites with oxygen in three proportions, two of which are found native, also with chlorine, iodine, sulphur, and phosphorus.

Lead.—This metal abounds in Scotland, Northumberland, Durham, and Derbyshire; some also is found in Devon. It was well known to the ancient Greeks and Romans, who applied it to a variety of purposes. Sheets of it fastened with nails of bronze were used to sheathe the bottoms of ships, just as our ships are sheathed with copper. Leaden pipes were also used for the purpose of conveying water, although the architect Vitruvius, who flourished in the reign of Augustus, reprehends the plan as being dangerous, well knowing that water, under certain circumstances, might be contaminated with the metal, and rendered poisonous in consequence.

The ancient Greeks and Romans knew that harsh wines could be rendered mild by immersing in them a piece of lead; but it was not known that the wines owed this mildness to the presence of a slow poison. During the first year of the Christian era, lead at Rome was twenty-four times as dear as it now is in Europe, whereas tin was only about eight times its present price.

Lead combines with oxygen in four different proportions, also with chlorine, iodine, bromine, fluorine, sulphur, phosphorus, and carbon.

TIN.—This is a beautiful white metal which is applied to a variety of useful purposes. Tin is found in Cornwall, South America, and various parts of the East Indies. The Cornish tin-mines have been celebrated from a very remote period. According to Aristotle, they were known in his time, and Diodorus Siculus, who wrote about forty years before Christ, gives an account of the method of working them. So renowned were the Cornish mines in the middle of the seventeenth century, that the celebrated Becher, a physician of Spire, and tutor of Stahl, came over from his native land, on purpose to visit them. Tin must have been known very early, as it is mentioned by Homer, and also in the book of Moses. An alloy of tin and copper was much employed by the ancients for the purpose of making edged tools, iron being at that time very expensive, and comparatively scarce.

Tin unites with oxygen in three proportions, also with chlorine, iodine, sulphur, and phosphorus.

IRON.—Iron is the most abundant, and certainly the most useful of all the metals. It has been known from periods of very great antiquity, and was employed by the ancient Jews, Greeks, and Romans, although not to any great extent, on account, I suppose, of the difficulty experienced in working it.

From a perusal of the fourth, eighth, and eighteenth chapters of Deuteronomy, it appears that iron was known in the time of Moses; and during the period of the Trojan war, the Greeks were acquainted with the method of tempering it, as may be learned from a perusal of Homer's Odyssey, in which he describes the firebrand driven into the eye of Polyphemus as hissing like red-hot iron immersed in water.

> ——"when arm'rers temper in the ford
> The keen-edged pole-axe, or the shining sword,
> The red-hot metal hisses in the lake,
> So in his eyeball hiss'd the plunging stake."

Iron is usually extracted from ores which are dug out of the earth, sometimes however it has been found nearly pure, and in large masses on the surface of the earth. In the museum of the Academy of Sciences at Petersburgh, there is a mass of native iron twelve pounds in weight. Iron has the curious property of being attracted by the loadstone, or magnet; and pieces of iron or steel may themselves be rendered magnetic, when they always point north and south. On this principle depends the mariner's compass, by which a ship's course may be directed day after day, although far from the sight of any land. It is not precisely known who discovered this very useful instrument. Some call him Flavio Giojo; others Giri, a native of Amalfi in Naples, at the beginning of the fourteenth century; but there are proofs that the use of the magnetic needle, in pointing out the north was known at an early period in Europe, and that a contrivance similar to a compass went under the name of *marinette* in France, as early as the twelfth century. The English first suspended the compass so as to enable it to retain always a horizontal position, and the Dutch gave names to the divisions of the card. The earliest missionaries to China found the magnetic needle in use in that country.

If two pieces of iron be made white hot and then hammered together they adhere, and form one piece. This operation is termed welding, and with the exception of platinum, is possessed by no other metal. Iron is used in the two conditions of wrought and cast-iron; the former is by far the purest variety, and is adopted for welding, but cast-iron can most easily be melted. I need not call your attention to the uses of iron: without the beauty of certain other metals, it surpasses them all in utility, and if deprived of it we should be reduced to a state of semi-barbarism.

Iron combines with oxygen in three proportions: iron-rust is a *per*oxide of the metal. It also combines with chlorine, fluorine, bromine, iodine, sulphur, phosphorus, and carbon. Steel and cast-iron are both carburets of the metal. Steel is made by heating iron for a long time together in contact with pieces of charcoal.

ANTIMONY is a brittle metal of a bluish white colour. It is seldom found pure but combined with sulphur as a sulphuret of antimony, which compound was formerly mistaken for the metal itself. Antimony enters into the composition of printers' types, and its compounds are much employed in medicine. Antimony was first described in the year 1490 by Basil Valentine, one of the alchemists, and acquired its name from a very curious circumstance. Valentine having administered some to pigs, found that it made them fat; wishing to fatten his brother monks, he gave them some, too; but instead of fattening them it killed them; hence the substance was called antimony, from anti, against or contrary to, and monachos, a monk.

Antimony combines with oxygen in three proportions, forming the sesquioxide of antimony, antimonious, and antimonic acids. It may be also made to unite with chlorine and iodine, while a combination of sulphur and antimony is found largely in a natural condition.

BISMUTH occurs in nature, both simple and in combination. It is a reddish white metal, brittle and very fusible. With oxygen it forms two combinations; with chlorine, bromine, and sulphur, one respectively: these I shall not stop to mention separately.

Zinc combines with oxygen in two proportions, forming oxides; it also unites with chlorine, iodine, fluorine, bromine, sulphur, and cyanogen.

ZINC is a bluish white metal, which was first described by Paracelsus, in the sixteenth century. At certain temperatures zinc is a very brittle metal, but at others it is both malleable and ducile, which enables it to be rolled or hammered into sheets of considerable thinness.

Zinc and copper may be made to combine together in several proportions, forming valuable alloys. Brass consists of one part zinc to four of copper: when more zinc than this is used, then compounds are generated, which are called tombac, Dutch-gold and pinckbeck.

ARSENIC OR ARSENICUM is an exceedingly brittle metal, of a strong lustre, and white colour, running into steel-gray. If thrown upon a hot surface arsenic flies off into vapour, which possesses a garlic odour. That dreadful poison, known in the shops by the name of arsenic, and sold in the form of a white powder, is in reality a combination of the metal with oxygen, and is called arsenious acid; besides this, there are two other combinations of arsenic with oxygen: it also unites with chlorine, iodine, bromine, and sulphur. White arsenic, or arsenious acid, is such an important substance, that we must very fully investigate its chemical properties by means of tests; but I think we had better finish our description of metals first, and then devote an hour or so to their tests alone.

COBALT is a brittle reddish grey metal, which derives its name from kobold, an evil spirit; because when combined with other metals, its presence renders them very difficult to be worked, and hence the superstitious miners thought that they were bewitched. Cobalt was long regarded with such horror as to give rise to the employment of a prayer, to the effect that miners might be protected from cobalt and all evil spirits. This metal, like iron, is attracted by the magnet, and may be rendered permanently magnetic.

Cobalt unites with oxygen in several proportions, also with chlorine, sulphur, and phosphorus.

Chlorine of cobalt dissolved in water, is used as a sympathetic ink. I write with a little of this solution on a piece of paper: at present the traces of the pen are not seen, but on holding the paper before the fire, every part which has been moistened by the chloride turns blue. Now the theory of this change is simple enough: chloride of cobalt possesses an affinity for water, when combined with this it is white, when the water is driven off the chloride is blue. Heat, then, by driving off the moisture effects the change which you observe.

If the cobalt be contaminated by iron or nickel, then the resulting sympathetic ink will yield not a blue but a green colour, and this is the substance employed in making those magic prints of trees, which in the cold appear leafless and bare, but when held before the fire, are adorned with the most luxurious foliage.

Nickel is a metal of a white colour, very hard and infusible, it is always a constituent of meteoric iron, or such as falls from the sky. Where these meteoric masses come from has never been satisfactorily determined. Some persons believe them to be shot from volcanoes in the moon; others that they are little wandering planets, or fragments of planets ;—but with this question chemists have nothing to do: we know that large masses of iron frequently *have* fallen upon the surface of the earth, and they have invariably contained the metal nickel.

However, we do not obtain it from this source, it is got from a copper-coloured mineral, called in German kupfer-nickel, or base copper, because the miners tried in vain to get copper out of it, and therefore thought it was bewitched. Perhaps this very word nickel may have given origin to our term "*Old Nick.*"

PLATINUM is the heaviest of all the metals, and a very valuable substance. In appearance it very nearly resembles silver; indeed, the word plati*na*, by which it is sometimes known, means little silver, being the diminutive of *plata.* It cannot be melted by the strongest heat of a furnace, but, like iron, it is capable of being welded. Platinum is not acted upon by the strongest acids, nor does it tarnish or rust by exposure to the air. It occurs in Brazil, Peru, and other parts of South America, generally in the form of flattened grains, which are rarely so large as a pea: however, it has lately been found traversing rocks in the form of veins, and there have recently been discovered valuable mines of it in the Uralian mountains.

Platinum unites with oxygen, chlorine, iodine, and sulphur.

MANGANESE never occurs native, but exists always in combination with oxygen, with which element it unites in no less than seven different proportions. The black, or peroxide of manganese occurs in various parts of the world. Sweden yields it in great abundance, and I need not remind you of the manganese-mines of Cornwall and Devon. A large quantity is also obtained from the Mendip-hills, in Somersetshire.

The black oxide of manganese we have already had occasion to use in the preparation of oxygen and chlorine: for the latter purpose a great quantity is employed by bleachers.

PALLADIUM.—Rhodium, iridium, and osmium are found mixed with grains of native platinum. Palladium is so called from the planet Pallas. Rhodium from rhodon, a rose, because of the rose-colour possessed by its compounds: iridium from iris, the rainbow, because of the various tints assumed by its various salts; and osmium derives its name from osme, smell, because its compounds have all a very strong odour.

And now, passing over a great many metals, the names of which you may see by the diagram, I come to a most extraordinary class indeed,—the class of alkaline metals. Ever since the first commencement of chemistry in Arabia, the term alkali, itself of Arabian origin, has been applied to the substances, soda, potash, and ammonia; lately the alkali lithia has been added to the number. I have proved to you that ammonia is a compound of nitrogen and hydrogen: *its* composition has been long known, but potash, soda, and lithia were at the same time imagined to be simple, or undecomposable substances. Judge, then, what was the surprise of the chemical world, when Sir Humphry Davy proved that those three alkalies were the rusts or oxides of as many different metals, which metals he obtained in a separate state. They have been named potassium, sodium, and lithium: the latter I have never seen, but I can show you specimens of the two others.

I have already had occasion to notice the vast power with which the voltaic battery is endowed in separating the elements of certain compounds. Water, when submitted to its agency, is resolved into *hydrogen* and *oxygen*, as I have already shown you: well, in like manner, potash, when galvanized, is resolved into *potassium* and oxygen; soda into *sodium* and *oxygen*, lithia into *lithium* and *oxygen*. Such is the method by which those metals were first prepared, but more recently there has been discovered a plan which is more easy to conduct, and which yields them in greater quantity. Potash, soda, and lithia, then, are merely the rusts or oxides of the three metals: *potassium*, *sodium*, and *lithium*, which have all such an excessive affinity for oxygen, or, if I may be permitted to use the term, such a *desire to unite with oxygen*, that their preservation becomes a matter of considerable difficulty. Lithium I have never seen, but here are specimens of potassium and sodium; you will remark that they are immersed in a fluid; this fluid is called naptha, and does not contain any oxygen, which circumstance renders it well adapted for our purpose. We are always accustomed to associate with metals the idea of great weight, yet potassium, sodium, and lithium, notwithstanding their metallic lustre, are all of them lighter than water.

I will now show you the metallic properties of potassium, for which purpose I take a little out of the bottle and cut it with a knife. See how bright and shining the cut surface appears;

in this respect it bears no distant resemblance to silver; but it has already tarnished or become oxidized from exposure to air, and the white covering which collects upon its surface is potash. The most wonderful property of potassium is that it takes fire immediately on touching water! or, to speak more correctly, it sets the *water on fire*—yes, actually *sets the water on fire!* therefore if we could find a sufficient quantity of potassium, the sea itself might be burned. I now throw a little bit of potassium upon some water in a basin; and see what results: the metal kindles into flame with an explosion, hissing and shining, it darts across the water like a little meteor, decreasing rapidly in size, it moves quicker and still quicker,—now it shoots around the basin, now across it; now it moves in circles, now it dashes about in irregular zig-zags: pop! and it is gone. Let us ascertain what has become of it.

Water, you know, is composed of oxygen and hydrogen, united together with a certain degree of force. Now combustion is nothing more than violent chemical action, attended with the evolution of light and heat. Oxygen is generally concerned in those violent chemical actions, and hence oxygen is one of the chief supporters of combustion. For instance, the ordinary combustion of a piece of charcoal is merely a rapid union of carbon with oxygen of the air. But if oxygen alone be required, why is it that charcoal cannot burn under water? The explanation is simply this:—atmospheric oxygen is uncombined, or, at all events, the combination is very slight; consequently, it may be regarded in the light of an individual who is perfectly free to do as he likes, and therefore no obstacle is opposed to its uniting with carbon, or the matter of charcoal. But the oxygen of water is in a very different predicament. We may regard it as a prisoner held in fetters by its gaoler, *hydrogen;* or we may fancy it a husband under the control of a self-willed and domineering wife; or, not to push our similes further, it may be compared to *any other* personage who cannot have his own way; in short, it cannot unite with carbon like the free and uncombined oxygen of the air. Carbon *may try* to get oxygen away from hydrogen, but all in vain. *Potassium*, however, is stronger than *carbon;* therefore when thrown upon water it separates *oxygen* from *hydrogen* by main force, and combining with it rapidly, gives rise to combustion; while potash is formed and dissolves in the remaining water. The liberated hydrogen uniting with a little potassium forms a spontaneously inflammable gas, called "*potassiuretted hydrogen.*" The water in the basin has now acquired a hot, burning, peculiar taste; I find that it renders yellow turmeric-paper brown, and restores the original blue colour to litmus-paper which has been reddened by an acid: these are properties of an alkali: in short, the water now contains the alkali, potash.

I need not go through the same process with the metal sodium; it is sufficient for me to mention, that, like potassium, it decomposes water with great rapidity, but does not usually give rise to combustion, except the water be so thickened by the addition of gum that the sodium cannot roll about.

I need scarcely tell you that potassium, possessing, as it does, such a violent affinity for oxygen, cannot exist in a free or uncombined state; combined, however, with oxygen in the form of potash, we find it in the animal, vegetable, and mineral kingdoms. Our own bodies contain it;* land-plants contain it; and among minerals which have potash entering into their composition, I may mention the substance called felspar, which is a constituent of granite. Potash is usually obtained from the ashes of land-plants by the following process. These ashes contain carbon*ate* of potash, or the alkali united with carbonic acid; a watery solution of which carbonate of potash is obtained by washing. To this solution lime is now added; carbonate of lime subsides, and potash is left dissolved in water; which, by the application of heat, may be driven off in vapour, potash alone remaining.* See how very shortly all these changes or decompositions, as they are called, may be expressed by means of a diagram.

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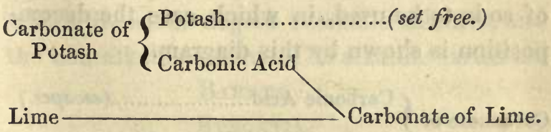
* Sodium, however, enters much more extensively into the composition of animals than potassium.



Potassium unites with chlorine, forming the chloride or chloruret of potassium: with iodine constituting the iod*ide* or iod*uret*, with bromine the brom*ide* or brom*uret*, and with fluorine the fluor*ide* or fluor*uret* of potassium; each of

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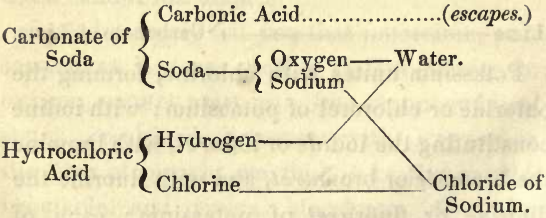
[*] Strictly speaking, a small portion of the water *cannot* be driven off even by the strongest possible heat, but remains in chemical union with the alkali.

which has its own uses either in the practice of medicine or the arts

Sodium, like potassium, unites with various simple substances; but I shall only speak of chloride or chloruret of sodium, which is common table-salt. This substance I need not tell you exists largely as a constituent of sea-water; indeed most countries are supplied with it from this source alone, but England derives its salt from mines situated in Cheshire, Worcestershire and Shropshire.

Chloride of sodium may be generated by burning sodium in chlorine gas; also by adding hydrochloric or muriatic acid to soda, or carbonate of soda. I will suppose carbonate of soda to be used, in which case the decomposition is shown by this diagram.



Formerly it was imagined that hydrochloric, or muriatic acid, and soda united together directly; and on this supposition common salt was called hydrochlorate or muriate of soda:—

indeed, it is not long since that the very term salt was exclusively applied to substances produced by the union of acids, either with metallic oxides, or with the alkali, ammonia; and since the discovery of the true nature of common salt, its very claim to the term salt has been disputed: indeed, many chemists of the present day, regardless of the violation they offer to ordinary language, assert that common salt is *no salt at all.*

Before the time of Sir Humphry Davy, not only were the alkalies *potash*, *soda*, and *lithia* imagined to be simple bodies, but also the substances known by the name of earths. Earths are divided into alkaline earths, or those which in some degree resemble alkalies, and the non-alkaline earths. The alkaline earths are

BARYTA,
STRONTIA,
LIME,
MAGNESIA.

The non-alkaline earths are

ALUMINA,
THORINA,
GLUCINA,
ZIRCONIA,
YTTRIA.

After it had been proved that the alkalies, potash, soda, and lithia were metallic oxides, the idea was not very improbable that alkaline earths might have a similar composition. Experiment soon settled this point. Baryta was found to be the oxide of a metal since called barium; strontia the oxide of a metal called by its discoverer strontium; lime, the oxide of calcium; and magnesia of magnesium. The five non-alkaline earths have been also found to possess a similar constitution; they are oxides of the metals aluminium, thorinium, glucinium, zirconium, and yttrium respectively: metals which are only obtained by tedious chemical processes, and which I have never seen.

About the earths I have not much to remark. Baryta and its soluble compounds are valuable tests for sulphuric acid, with which they throw down an insoluble sulphate of baryta. Strontia derives its name from Strontian in Scotland. Lime is found in the animal, vegetable, and mineral kingdoms: it is usually obtained by exposing chalk or marble, which are carbonates of lime, to a strong heat; carbonic acid is expelled, and lime in a pure state remains. (See p. 147.) Magnesia is obtained in a similar manner from carbonate of magnesia.

I now conclude the subject of metals, and I am sure it is quite unnecessary for me to remind you of their immense importance in the grand economy of nature as well as in the arts of civilized life. Suppose we were deprived of iron alone: what misery, what confusion would result, and to what primeval barbarism should we be again plunged: no ploughshares to cultivate the ground; no swords to repel our foes; no vast machinery to abridge our labours, and multiply our riches; no compass to direct the mariner across the deep: half the genius, the wisdom, the intellect imparted by the Almighty to mankind, would have no scope for its exercise, and we should be little removed from those primitive savages who lived upon acorns and wild berries. But why do I talk thus?—without iron we could not have existed, for it enters into the composition of our blood.

LECTURE XVIII.

SUBSTANCES WHICH ARE FORMED BY THE UNION OF COMPOUNDS WITH EACH OTHER.

OUR labours in chemistry are drawing towards a conclusion, and I shall very soon bid the subject farewell: it was never my intention to engage you very deeply in the science, but merely to take a passing glance at its wonders, and its beauties

We have hitherto regarded simple bodies as combining together and forming compounds; but we have taken no account of the combinations which occur between compounds themselves: of these there are a very large number, and the nature of some of them is not at all easy for a beginner to understand. Their composition was formerly much more difficult to remember than at the present time, because chemical substances were named after no fixed rule, but only according to the whim and caprice of their discoverers.

Amongst the successful labours of modern chemists the method of naming substances in a manner to indicate their composition stands high in the scale of practical utility. You may already have formed some idea of its importance, although I have not directed your attention exclusively to the matter. The term chlorine indicates that the gas is greenish; hydrogen means the water-former, and oxygen the acid-former, because chemists imagined that every acid contained it. This opinion is incorrect, since *every* acid does *not* contain it; yet the greater number do, and therefore the term oxygen may still be retained with considerable propriety.

It is always taken for granted that an acid contains oxygen, except the contrary be expressed. By the term sulphuric acid I understand an acid composed of sulphur and *oxygen;* by *hydro*-sulphuric acid, an acid composed of sulphur and *hydrogen*. When oxygen only forms two acids with a substance, then the name of the acid which contains the *smaller* proportion of oxygen is made to end in *ous:* and of the one which contains the *larger* proportion of oxygen in *ic*. If there should exist more than *two* combinations, then we are obliged to have recourse to *Greek* and *Latin words.* I may illustrate what I mean by referring to the compounds of sulphur and oxygen. Formerly only two such compounds were known; one composed of one atom sulphur and two atoms oxygen, and the other of one atom sulphur and three atoms oxygen; the former was called sulphur*ous*, and the latter sulphur*ic* acid. More recently there have been discovered two other compounds of oxygen and sulphur; one of which contains less oxygen than sulphur*ous* acid, and the other more oxygen than sulphurous, but less than sulphur*ic* acid; hence they are respectively called *hypo*-sulphur*ous* and *hypo*-sulphur*ic* acids; hypo, or upo, meaning under or less. In this diagram the two original compounds of sulphur and oxygen are represented by capitals; the two others by small Roman letters.

	Sulphur.	Oxygen.
Hypo-sulphurous Acid	2	2
SULPHUROUS ACID	1	2
Hypo-sulphuric Acid	2	5
SULPHURIC ACID	1	3

Now, before the introduction of this new nomenclature, sulphuric acid was known by the name of oil-of-vitriol; a name which gives us no useful information whatsoever, indeed it misleads us, for the so-called oil-of-vitriol is *no oil at all.*

If an acid whose name ends in *ic* combine with a substance, the name of the compound is made to terminate in *ate:* for instance, sulphur*ic* acid with soda forms sulph*ate* of soda. If an acid whose name terminates in *ous* combine with a substance, then the name of the resulting compound is made to terminate in *ite:* for example, sulphur*ous* acid with soda forms sulph*ite* of soda. When a simple substance unites with oxygen, and does not form an acid, the compound is simply termed an oxide. In like manner the combination of iodine, chlorine, bromine, sulphur, and fluorine, with other simple substances, forms chlorides or chlorurets, iodides or iodurets, bromides or bromurets, sulphides or sulphurets, and fluorides or fluorurets. But the advantages of the new system of nomenclature are best displayed by some other examples which I now mean to give you.

The chemist, Glauber, discovered a salt, which was long known by no other appellation than *Glauber's salt ;* but this name conveys very little useful information indeed;—merely giving us to understand that Glauber was, in some manner or another, connected with it; a matter of very slight importance. Now Glauber's salt being a compound of sulphuric acid with soda, the framers of the new nomenclature called it sulph*ate* of soda, a term which immediately bespeaks its composition, and affords us a very useful piece of information.

Again, there exists a substance commonly known by the name of sal-ammoniac; but what information does this convey? none at all: whereas the term hydrochlorate of ammonia, informs us that it is a compound of hydrochloric acid and ammonia. Having now made such remarks upon the system of chemical nomenclature as are necessary for you to be acquainted with, I bring the subject to a conclusion. Its consideration may not appear a very agreeable study, but it is nevertheless a very useful one, and will enable you to overcome many of the apparent difficulties in chemistry. I am sure, then, you will not refuse to devote a little time and attention to the purpose of acquiring it. Remember, a child does not derive much pleasure in learning his alphabet, yet it would be a pity indeed that he should be debarred from all the riches of literature and science, merely because of the annoyance to be endured in first learning his letters.

Among the various substances which are generated by the union of compounds with each other, the class of bodies called salts is by far the most important: and yet if you ask me what I mean by the term salt, I confess I cannot very well answer you; it is a point on which chemists are not exactly agreed. If I add sulphuric acid to soda, sulphate of soda results; if I add nitric acid to the same alkali, I obtain nitrate of soda; both of these substances are termed salts, and the alkali soda is said to be their base. By adding hydrochloric acid to soda, common table-salt is obtained; which substance chemists for a long time considered to be hydrochlorate of soda, but now it is known to be chlor*ide* of sodi*um*, or a direct union of chlorine with sodium. Hydrochloric acid is not the only one which does not unite directly with bases, for hydriodic acid, hydrobromic acid, and, in short, all the hydracids demean themselves in a similar manner. Still those acids yield compounds in appearance and general properties very much resembling salts, which are formed by the union of an acid with a base. The question, then, resolves itself into this—shall the chlorides, iodides, bromides, and fluorides be called salts, or shall they not? Well, it is not for me to determine this point, but I think it rather a startling assertion to affirm that common table-salt is no salt at all. However, we need not teaze ourselves about a mere definition: whether common salt be really a salt, chemically speaking, or no salt at all, it is nevertheless *chloride of sodium*, and we may ascertain its properties just as well under one name as another.

I have already said what I consider necessary about chloride of sodium, as well as some other disputed salts; therefore we will now investigate the properties of a few of those substances which every one admits to be salts, as being composed of an acid and a base.

Nitrates, or combinations of nitric acid with bases.

As one of the most important of the nitrates, I may mention the nitrate of potash, called also saltpetre, or nitre: and now, in order to give you a true idea of the composition of this salt, I will go through the process of making it.

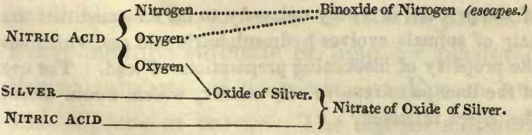
First, then, I add nitric acid, much diluted with water, to carbonate of potash; pure potash would do but it is very expensive, and carbonate of potash answers just as well. The mixture hisses and bubbles like a glass of soda-water, because nitric acid seizes the potash, and sets carbonic acid, in the form of gas, at liberty. The effervescence or bubbling has ceased, and the solution contains nitrate of potash. This nitrate of potash cannot be converted into vapour by heat, although water can; therefore, if I make the solution hot, water is driven off in the form of vapour, and nitrate of potash remains behind: if the heat be applied too long, the salt is obtained in a shapeless mass; but if the heat be discontinued as soon as a pellicle is seen to form on the solution, then we get nitrate of potash in crystals. There are several methods of crystallizing bodies, but the most usual way is by the process of evaporation.

Nitrate of potash is a most valuable salt, and we should be badly off indeed if it could only be made by adding nitric acid to carbonate of potash. It is used both in medicine and the arts. Gunpowder is a mechanical mixture of nitre, sulphur, and charcoal. In various parts of the world great quantities of nitre exist as a natural product. We derive our supply of it from the East Indies, but a great proportion of that employed in France and Sweden is made artificially, not in the way I have shown you, but by exposing certain mixtures of animal and vegetable substances to the action of the air. This method of obtaining nitre was a discovery of the celebrated French chemist, Berthollet. France at one period of the revolution was nearly prevented from carrying on war against her enemies, on account of a deficiency of nitre. Like England, she had been accustomed to receive her supply from the East Indies, but at the period to which I allude, her intercourse with those regions was prevented by the vigilance of the English fleet. Matters were in a most precarious state, and Bonaparte applied to his philosophers for assistance. The application was not in vain; nitre was made at home instead of being imported from abroad, and during a great number of years France was supplied with this article by her own manufactories.

Nitric acid when united with soda forms nitrate of soda; with ammonia, nitrate of ammonia.

There are but few metals which do not yield each an oxide capable of uniting with acids and thus becoming the base of a salt. We have already seen that potash, or the oxide of potassium, combines with nitric acid, forming nitrate of potash. In like manner it unites with oxide of silver and oxide of copper, forming nitrate of oxide of silver, and nitrate of oxide of copper respectively: also with oxides of other metals, forming as many different nitrates. It is more usual to say nitrate of silver, nitrate of copper, and so on, than nitrate of *oxide of silver*, nitrate of *oxide of copper:* this omission, however, is merely for the sake of abbreviating a long name; and now I wish you to remember that acids *never* combine with *metals*, but with *oxides* of *metals*.

Nitrate of silver is thus made. Pour upon the metal silver some nitric acid mixed with water. Violent chemical action immediately ensues. Silver in the first place takes oxygen from nitric acid to form oxide of silver, which, combining with undecomposed nitric acid forms nitrate of the oxide of silver, and binoxide of nitrogen escapes.



By the process of evaporation nitrate of silver may be obtained in crystals, and these crystals when melted, form lunar-caustic, a substance much used by surgeons. A solution of nitrate of silver stains animal and vegetable substances of an indelible black; hence it is employed for the purpose of marking linen, and also to blacken red hair and whiskers; however, it blackens the skin no less than the hair, which circumstance has caused hair-dressers to invent other dyes which are free from this objection.*

Nitrate of copper may be prepared in the same manner as nitrate of silver, merely substituting one metal for the other.

Most of you know that touch-paper is made by drying paper which has been dipped in nitrate of potash. Now any salt which is capable of making touch-paper, must be either a nitrate, an iodate, a chlorate, or a bromate. On a little nitre, mixed with copper-filings, I now pour some oil-of-vitriol:—red nitrous fumes are immediately liberated; a salt which makes touch-paper, and when mixed with copper-filings evolves red fumes on the addition of sulphuric acid *must be a nitrate.*

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* The most approved hair-dyes consist of a mixture of oxide of lead and lime. In order to understand the theory of the process, it is only necessary to be informed that the hair of animals evolves hydrosulphuric acid gas, which has the property of blackening preparations of lead. The use of the lime is to remove oily matter, which would defeat the object intended.

Chloric, iodic, and bromic acids unite with bases forming chlorates, iodates, and bromates; salts which in many of their properties are very similar to nitrates.

Carbonic acid unites with bases and forms salts, which are termed carbonates. They are distinguished from other salts by effervescing when acted on by acids; this effervescence depending upon the escape of carbonic acid gas. Marble and chalk are two different forms of carbonate of lime, and white-lead, used in painting, is a carbonate of that metal. Many of the carbonates occur native, among which I may mention carbonates of soda, baryta, strontia, lime, magnesia, and of the protoxides of manganese, iron, copper, and lead.

Sulphuric acid by combining with bases forms sulphates, which may all be prepared artificially, but some exist as natural products. I may mention sulphate of lime, or plaster of Paris; sulphate of magnesia, or Epsom salt, and sulphate of baryta. The test for sulphuric acid and sulphates is a soluble salt of baryta, as I explained to you on a former occasion.—(*Page* 161.)

Phosphoric acid by combining with bases forms phosphates; phosphate of lime enters largely into the formation of bones, and was formerly known by the term *bone-earth*.

The borates, or combinations of boracic acid with bases, are none of them very important if we except biborate of soda, commonly called borax, a substance much used in medicine and the arts.

Silicic acid combines with bases, and forms salts, called silicates, which are a very numerous and important class of substances. The silicates are found very abundantly in nature: clay is an active silicate of alumina, and therefore, without any impropriety of chemical language, we may affirm, that the very cups and saucers are masses of a salt, and also the brick-walls which compose our dwellings. The finest porcelain was formerly manufactured in China, the necessary mixture of silicic acid and alumina being obtained by blending together two materials, called respectively by the Chinese *kaolin* and *petunsi*. Without possessing the advantage of these substances, other nations have, at length, far outstripped the Chinese in this very beautiful manufacture. The making of china-ware is now extensively carried on in England, Prussia, and France. Instead of using kaolin and petunsi, European nations are under the necessity of employing a mixture of clay and powdered flints, from which is obtained a ware of equal, if not superior, beauty to that prepared in China; while the excellence of design and colouring are infinitely beyond any thing of the kind ever accomplished by the Chinese.

The preparation of earthenware is divided into a great many separate operations. In the first place, a mass of prepared clay is moulded into a shape somewhat like that intended, by the hand alone; afterwards the circular parts are turned in a lathe, and the various ornaments, such as flowers and leaves in relief, handles, and so forth, are cast in moulds and stuck on separately. The vessel thus fashioned into its requisite form is allowed to dry, when the various colours are laid on;* and it is then baked to cause partial fusion: afterwards it has to be glazed, which is effected by covering it with a thin layer of some easily fusible substance, and then exposing it to heat again, which causes the glaze to melt, and the ware to be covered with a thin layer of glass.

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* Blues are produced by preparations of cobalt;—bright red and purple by preparations of gold;—yellow by chromate of iron, and green by preparations of copper.

Among the most useful of the artificial compounds of silicic acid must be mentioned glass, of which there are various kinds, differing in the nature as well as in the quality and relative quantity of their components. Thus we have given bottle-glass, window-glass, flint, and plate-glass. Green bottle-glass is a silicate of soda and iron, made with very impure and coarse materials. Window-glass contains less iron, and is composed of materials altogether more pure.

Plate-glass contains no iron, and is a silicate of soda, almost uncontaminated. Flint-glass is a silicate of soda and of oxide of lead, the latter substance rendering it exceedingly fusible, and, consequently, well adapted for being formed or fashioned into different shapes. Window-glass is blown into immense bubbles or globes, which being cut open whilst in a soft condition, and allowed to expand on flat iron surfaces, form the flat pieces, or sheets, which we see. Plate-glass, however, is not blown but cast in large iron frames, and subsequently polished; hence it is a far more expensive material. It is necessary that instruments of glass should be allowed to cool very gradually, otherwise they are subject to fracture from the slightest causes; the external parts quickly becoming solid, and acquiring their utmost contraction, whilst the internal parts have not been enabled to accomplish this, and hence they are continually endeavouring to arrange themselves differently. To obviate this inconvenience, glass, after having been formed into any shape, undergoes a process called annealing, which consists in passing it gradually through a long oven or furnace, one extremity of which is very hot and the other quite cool. Now, by means of a proper contrivance, the glass articles are gradually pushed from the hot to the cool extremity, and thus every facility is given their particles to contract with equability. This process of annealing occupies a time more or less extended in proportion to the size of the vessels undergoing the operation ; hence it is that illegal glass-works, in which the operations are carried on by stealth, and the process of annealing gone through in a hurry, never turn out good and lasting articles : many, indeed, appear as perfect and transparent as those procured from legal sources, but a slight blow, or a little warm water is generally sufficient for their destruction.

And now, before concluding this limited account of salts, let me direct your attention to the wonderful and startling changes effected by combination. Who would have imagined that Epsom salt contained oil-of-vitriol; that marking-ink contained silver; that iron, lead, copper, and indeed every other metal, might all be rendered soluble? Who, I say, would have imagined them capable of such alteration? We may compare the elements of this globe to persons at a masquerade; we may compare them to the fabled metamorphoses of the poets, who represented inanimate things changing into living forms, and human beings into beasts, trees, and stones; in a word, we may give wing to fancy, and bid her skim the regions of romance to find wonders for our admiration; yet fancy herself could never have invented half the ideal changes of form, which chemistry shows us in reality. But although bodies are so continually altering their combinations, and assuming different forms, colours, and conditions, yet they are endowed with certain properties which never change; properties of which the chemist alone is aware, and the knowledge of which is a master-key, admitting him to the deepest mysteries.

It requires no great penetration to distinguish between a piece of iron and a piece of silver; but if these metals were in the state of solution, something more than ordinary experience would be absolutely necessary to enable one to form an opinion.

A person unacquainted with chemistry, on being shown two solutions each as limped as water, would immediately conclude that neither of them could by any possibility contain a metal. Such a person has already formed his opinions and associations; when thinking about a metal, he brings to his mind the ideas of hardness, opacity, and great weight: if told that a certain transparent solution contained iron, he would probably figure to himself a nail immersed in a glass of water, as a self-evident means of contradicting the assertion. The chemist, on the other hand, does not associate with iron the qualities of opacity, hardness, or weight, as *indispensable to its existence*, he merely regards them as *indispensable to iron in an uncombined state*.

LECTURE XIX.

ANALYTICAL CHEMISTRY—TOXICOLOGY, OR THE CHEMISTRY OF POISONS.

THE operation by which we are enabled to discover the chemical composition of any substance is termed analysis, a word which means unloosing or pulling to pieces. We are all of us, to a certain extent, analytical chemists, however unconscious we may be of our power. In order to illustrate this position, I will take an example; I will suppose that a piece of platinum and a piece of lead are given to a person totally ignorant of chemistry, with a request that he would distinguish the one from the other. Now lead is soft; platinum is soft also; lead is whitish, so indeed is platinum; it is evident that some other distinction is required. Our novice would now probably try the effect of heating his metals: one melts with great facility, the other does not melt at all; and *now* it is quite evident which metal is lead.

By proceedings no less rational than this, although rather less evident, the chemist performs his most elaborate analyses, and is able to discover, as if by magic, small quantities of substances entering into the most complicated mixtures:—to demonstrate that a body many years buried was a victim to poisoning;—to separate this poison, and exhibit it in a court of justice; to detect less than the thousandth part of a grain of iron, lead, arsenic, or other metals, although dissolved in a hogshead of water; and to arrive at many other conclusions no less wonderful and useful. It requires a study of many years to make an expert analytical chemist; but to understand the first principles of analysis is not at all difficult. I have before me solutions of four different metallic compounds; sulphate of iron, sulphate of copper, nitrate of silver, and nitrate of lead. We will now proceed to test them, so as to distinguish one from another. The tests I shall employ are:—

A solution of hydrosulphuric acid.
——— ferrocyanide of potassium.
——— ammonia.
——— common salt.
——— iodide of potassium.

I will suppose we have been informed that each of the solutions contains a metal, but we do not know what the metals are.

Now solutions of all those metals which form with oxygen, alkalies, and earths, are neither affected by hydrosulphuric acid nor by ferrocyanide of potassium.

Solutions of nearly all the remaining metals *are* affected *either* by *hydrosulphuric acid*, or by *ferrocyanide of potassium*, and all of them except five, namely, *uranium*, *iron*, *manganese*, *cobalt*, and *nickel*, by hydrosulphuric acid alone.

First, then, I test a little of each liquid with hydrosulphuric acid. The silver, lead, and copper solutions are blackened, but the iron one remains unaltered. Hydrosulphuric acid strikes a black colour with many metals, but with arsenic and cadmium it produces a yellow, and with antimony a red colour; therefore our solutions contain neither of these.

Now I add to each liquid ferrocyanide of potassium, which strikes with the iron solution a deep blue, with the copper one a brown, and with the silver and lead it yields white precipitates. No metal except iron yields with this substance a blue colour; therefore we have already determined what one solution contains.

Again, only four metals, copper, uranium, tantalium, and molybdenum, yield a brown colour with this test; the three latter are so rare that, for all practical purposes, we may consider it determined that copper is the metal ; however, in order to be quite certain, I add to some of the questionable liquid a little of the solution of ammonia, which affords a blue colour, and proves to me that the solution *must* contain copper.

To some of the two remaining liquids, very much diluted,* I add a solution of common salt; when immediately in one glass there fall down white curdy flakes, and these are soluble in ammonia; which facts, taken conjointly, prove that the solution contains silver. To the remaining liquid I add iodide of potassium, and obtain a *deep yellow* precipitate, by which I know that lead is present. Salts of silver also afford a yellow precipitate with iodide of potassium, but a very *light* yellow. Now we may construct a table of the colours produced by tests on the four metals, *iron*, *silver*, *lead*, and *copper*.

	Iron Solution.	Silver Solution.	Lead Solution.	Copper Solution.
Hydrosulphuric acid	—	black	black	black.
Ferrocyanide of potassium	blue	white	white	brown.
Chloride of sodium	—	white	none in weak solutions	—
Iodide of potassium	—	light yellow	deep yellow	—

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* Chloride of sodium will throw down or precipitate with solutions of silver salts, however much they may be diluted ; but only with *strong* solutions of salts of lead.

We have hitherto merely ascertained what metal each of the four solutions contains; but metals, I have before remarked, are not soluble except in combination, and consequently our information respecting the solutions is not yet complete. I now proceed to test each of the four solutions for substances which enable the metals to be dissolved. First, then, I add to the iron and copper solutions a few drops of a solution of hydrochlorate of baryta, and immediately you observe there falls a copious white precipitate, which I find is quite insoluble in boiling nitric acid;* in fact it is sulphate of baryta, and hence I know that each of the two solutions contained sulphuric acid. One consisted of sulphate of oxide of iron, and the other of sulphate of oxide of copper.

Again, I find that the silver and lead solutions do not afford a precipitate with hydrochlorate of baryta, and this fact supplies me with the negative information that neither of them contains sulphuric acid. I find, however, that by dipping a piece of paper into either of these solutions I convert it into touch-paper, and from this fact I learn that they must contain either nitric, iodic, bromic, or chloric acid.†

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* Page 161.

† Page 242.

For all practical purposes the question is already settled;—as the three latter acids are very rare indeed; but in order to be quite certain I evaporate a little of each solution to dryness, and add to the residue, mixed with filings of copper, a small quantity of sulphuric acid; immediately there appear red fumes of binoxide of nitrogen, which could only have been liberated from nitric acid, (*see* p. 243,) therefore one solution contained nitrate of oxide of lead, and the other nitrate of oxide of copper.

The operation which we have just been performing is called testing, and consists merely in ascertaining the nature of ingredients entering into a mixture, without endeavouring to separate them, or to discover their relative proportions. It is quite possible, by means of a series of operations, rather more complicated than those which I have been describing, to separate the acids from the metallic oxides, and even to separate the metals from oxygen; but as I am only giving a faint outline of analytical chemistry to young beginners, I shall content myself with showing how metallic silver may be separated and obtained in a pure state. Into the silver solution I immerse a clean slip of copper, and a few seconds having elapsed, you observe that the silver has been deposited in the form of bright metallic scales. There are several other means of accomplishing the same result, but this is the easiest to be put into execution.

That branch of analytical chemistry which relates to the discovery of poisons and the treatment of poisoning, is called toxicology from *toxon* a bow; the term evidently conveying an allusion to poisoned arrows. The science of toxicology has lately been brought to an amazing degree of perfection, and, at the present time, is cultivated by some of the most celebrated chemists. Formerly, if a person should by chance have the misfortune to swallow poison, he was treated altogether at random; the usual remedy was soap-suds, which, indeed, in some cases of poisoning is really beneficial; in others is of no use whatever. We now act on more philosophic principles, and in the majority of cases death is prevented by a timely interposition of art.

Poisons may be divided into those which exert a mechanical, and those which exert a chemical agency: for instance, a quantity of broken glass if swallowed will kill by lacerating the coats of the stomach; this is a mechanical agency. Oil-of-vitriol, aquafortis, and spirit-of-salt (the sulphuric, nitric, and hydrochloric acids) act by setting up violent inflammation, and perforating the stomach; these are chemical poisons. One of the greatest wonders in chemistry is the entire change which certain substances undergo by combination. Sulphuric acid, or oil-of-vitriol is a deadly poison. Epsom salt, or sulphate of magnesia, a body which contains sulphuric acid, is quite harmless. If, then, a person had inadvertently swallowed sulphuric acid, would not common sense prompt a chemist to administer magnesia, with which the acid might combine, and form Epsom salt? This, indeed, is the most suitable plan of treatment that can be followed. But how is the magnesia to be administered? it cannot be given in the form of dry powder; nor mixed with water, for water and sulphuric acid when they come in contact with each other develope a high degree of heat: mix the magnesia with milk, and even with a very small quantity of this fluid.

Chemical action takes place with the greatest facility, when the agents are in a state of solution; therefore the rapidity of action possessed by a chemical poison is in the ratio of its solubility: if by any means we can render it insoluble, then it ceases to be a poisonous agent. All the soluble compounds of the alkaline earth baryta, and, indeed, *any solutions* containing the metal barium are violent poisons—but baryta and sulphuric acid form a compound which is quite insoluble, and hence, quite harmless. If, then, a person had taken a salt of baryta, or, indeed, any solution of barium, theory requires the administration of sulphuric acid; but this substance itself is a poison, therefore a dose too much would obviate all our good intentions; besides, it would burn the throat before arriving at its destination, the stomach; what, then, is to be done? We must administer some compound which contains sulphuric acid in a harmless form, and none is more generally available than Epsom salt. This substance is also an antidote for preparations of lead.*

Again, a person may have swallowed oxalic acid, which in a few minutes will certainly kill him, if remedies be not at hand. Oxalic acid when combined with lime is inert; but lime, too, is a poison: give, then, some form of *carbonate* of lime: run to the kitchen for some whiting; get a lump of chalk; or if neither be at hand, quickly knock down a piece of the wall, and administer it mixed with milk or water; do this immediately, and the individual is *certainly* saved; but wait a few minutes, and he as *certainly* dies!

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* Because sulphate of lead is insoluble.

A person may have been poisoned with preparations of copper, or of mercury; generally the bichloride or corrosive sublimate; what *then* is to be done? Give the white of eggs beat up with water, *immediately*, and the patient is *secure.* These are a few examples of the triumphs of chemistry, and it is much to be regretted that antidotes still remain to be discovered for a considerable number of poisons, the ill effects from which can only be prevented by removing them from the stomach, either by emetics or the stomach-pump.

There is not yet discovered any satisfactory antidote for white arsenic, (arsenious acid,) cases of poisoning from which are of such frequent occurrence; but even in this instance it is very proper to administer white of egg, which does not effect any chemical change on the poison, it is true, but yet acts beneficially, by sheathing the stomach.

I promised that I would show you the tests for white arsenic, and how to separate it from a solution, which I shall now proceed to do.

Into one glass containing a solution of this poison I throw some lime-water, and a white precipitate falls. Into the second glass of solution I let fall two or three drops of a solution of nitrate of silver, and a single drop of hartshorn, (solution of ammonia,) when a yellow precipitate falls: into the third glass I pour a small quantity of solution of sulphate of copper, together with a drop of hartshorn; a green precipitate falls: and through the solution contained in the fourth glass I pass a stream of hydrosulphuric acid gas, which throws down a yellow precipitate; orpiment, or sesqui-sulphuret of arsenicum. Nothing besides arsenious acid would have afforded the same appearances with the same tests. *I* could have sworn that the solution contained arsenious acid from the appearances elicited by the foregoing tests; but in a court of justice further information is necessary: the *poison itself must be produced.*

There are two methods of effecting this, but I shall only mention one. Either of the four precipitates just produced is to be mixed with a substance called black flux,* and exposed to heat in a glass tube, when shining metallic arsenicum arises and lines the tube with a grey crust. This crust of arsenicum, if again heated, absorbs oxygen, and forms white arsenic, the poison, which deposits in little crystals. The process of obtaining metallic arsenicum from a precipitate is termed the reduction test. All the various tests here described may be advantageously condensed into a tabular form.

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* Black flux is composed of pure carbonate of potash and charcoal, made by throwing into a red-hot crucible a mixture of nitre and cream-of-tartar.

TESTS FOR ARSENIOUS ACID, OR WHITE ARSENIC.

Lime-water.	Ammoniacal Nitrate of Silver.	Ammoniacal Sulphate of Copper.	Hydrosulphuric Acid.	Reduction Test.
White.	Yellow.	Green.	Yellow	Metallic coat of Arsenicum.

For opium, henbane, nux-vomica, and, indeed, the majority of poisons derived from the vegetable and animal creations, there exist no satisfactory antidotes. This remark equally applies to hydrocyanic, or prussic acid.

In discussing the subject of toxicology I may have gone into many dry and tiresome details; but the importance of this branch of chemistry demands our most especial attention. Operations connected with some sciences need only be remembered in their general principles; the particulars being ascertained when convenient by reference to books,—the delay of a few minutes, hours, or perhaps days not proving of the least consequence; but all that department of toxicology which relates to the administration of antidotes should be impressed on your memories, firmly as the letters of the alphabet: the application of your knowledge *this* minute may save the life of a fellow-being; *the next* may be too late.

In order that the antidotes for poisons may be easily remembered, I here present them in a tabular form.

POISONS.	ANTIDOTES.
Sulphuric Acid Nitric Hydrochloric	Magnesia (calcined) or Carbonate of Magnesia, or some form of Carbonate of Lime, as whiting, chalk, administered in milk.
Oxalic Acid.	Any form of Carbonate of Lime, mixed with milk or water.
White Arsenic.	*None.* Administer thirty grains of white vitriol (Sulphate of Zinc) as an emetic,[*] tickling the back part of the mouth and throat with a feather to promote its action; give also white of eggs, beat up with milk or water. See p. 259.

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[*] A very efficient emetic is a tea-spoonful of mustard administered in a cup of warm water; it has, moreover, the additional advantage of being generally at hand.

POISONS.	ANTIDOTES.
Preparations of Copper and Mercury.	White of egg beat up with milk or water.
Preparations of the metal Barium and its oxide Baryta. Preparations of Lead.	Epsom Salt.
Opium.	No antidote on which any reliance can be placed: administer thirty grains of white vitriol, tickle the back part of the mouth and throat with a feather. *Do not give vinegar*;[*] neither must you allow the patient to sleep. Keep him awake by every possible means: make him walk up and down a yard between two men: if he *then* sleep, push a needle or a pin under his nail to the quick, and dash cold water over his head.

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[*] This was formerly recommended; but there cannot be a worse practice. The active principle of opium is morphia,—an alkali:—the solubility, and consequent activity of which is much increased by combination with acids.

LECTURE XX.

REMARKS ON GRAVITATION, COHESION, AND AFFINITY — SINGLE AND DOUBLE ELECTIVE AFFINITY—SINGLE AND DOUBLE DECOMPOSITION.

HAVING now gone through that portion of chemistry which relates to beings without life, I purpose introducing you to another department of the science; to organic chemistry, or the chemistry of living beings. But previous to our entering upon this wide and very interesting field it will be advantageous for us to take a retrospective view of the regions we have already traversed. Anxious to avoid burdening your memory with more than was absolutely necessary, and to refrain from announcing laws and properties before you had been made acquainted with instances of their operation, I have not said much respecting the attraction to which all material things are subject. There are usually mentioned three kinds of attraction, gravitation, cohesion, and chemical attraction or affinity. To the former I have already made allusion, and to a certain extent explained it; but the very great importance of this attraction demands that we should pay it still further attention. Gravitation may be defined to be the force which causes bodies to approach each other's centres: acting in straight lines at sensible and often very great distances, and decreasing in power as the square of the distance increases;* this distance being calculated from the centres of gravitating masses. I have already proved† that all bodies owe their weight to the operation of this force.

I have mentioned that the farther bodies are removed from the centre of the earth, or point of terrestrial gravitation, the less does their weight become; and I have contented myself with referring the decreased weight of bodies at the equator to the fact of their increased distance from the centre alone. But this explanation is only partial; we must seek for some anterior cause: we must *account* for this increased distance, and show *why* the equatorial diameter of the earth exceeds the polar.

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* A square in arithmetic is any number multiplied by itself:—thus 4 is the square of 2, and 9 of 3.

† Page 25.

The shape of this planet when first created is supposed to have been a sphere;* which supposition granted, every point on its surface must have been equidistant from the centre, and the power or force of gravitation must have been the same whether at the equator or at the poles. But the earth was caused to whirl round on an axis with great rapidity,† by the agency of another force, termed the centrifugal, and in consequence of which all the particles of the earth, except such as might be situated in the geometrical axis of rotation, were disturbed, and driven by main force towards some part of the circumference of the planet. Those particles which were situated farthest from the geometric axis were of course most subject to the influence of the centrifugal force, or, in other words, were caused to move faster, and consequently were driven farthest away. Therefore it appears that the cause why bodies at the equator weigh less than at the poles is *ultimately* referrible to the increased equatorial motion, produced by an increase of the centrifugal force, which has caused the earth to assume its present oblate spheroidal shape, and *immediately* or *proximately* referrible to the increased equatorial diameter thus produced.

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* Of course no account is taken of its various hills and mountains, the general figure of the earth being no more interfered with by such little excrescences than is the figure of a billiard-ball altered by little particles of dust which adhere to its surface.

† This is the diurnal motion of the earth; the cause of day and night. Its rate of velocity differs for different parallels of latitude, the inhabitants of the equator being carried by this motion 1042 miles every hour, and those under the parallel of London about 644 miles in the same space of time. Besides this diurnal motion, which alone has connexion with terrestrial weight, the earth and its inhabitants are subject to another, the annual motion, or rotation round the sun; this is at the rate of more than 68,000 miles per hour, and is participated *equally* by every inhabitant on the globe, whereas the diurnal motion is *not.*

The agency of a centrifugal force may be very simply illustrated by an experiment. If a perfect globe or sphere of any soft and readily-yielding substance, such as clay, be perforated through the centre by a stick, and if by means of this stick as a handle or axis, it be made to revolve rapidly, its globular form will be destroyed; and becoming flattened around the two points which are perforated by the stick, it will everywhere else bulge out in such a manner that the diameter, which is traversed by the stick, will be shorter than any other: that diameter which is at right-angles to the stick, or which lies directly across it, being the longest.

The attraction of cohesion is altogether different from gravitation, and, as the term indicates, it means a sticking together. I take a piece of marble, and having lifted it from the ground, I let it fall. By the agency of gravitation it is brought to the ground, and on account of the sudden shock it breaks in pieces, because its attraction of cohesion has been overcome. Cohesion, then, was the attractive force which kept the particles of marble in contact with each other, and this attraction being overcome, the particles separated. However near I approximate these pieces of marble together, I cannot make them approach so near as is requisite for bringing them within the sphere of each other's cohesive attraction, and for causing them to join again into a mass; therefore cohesion is said to exert its force at *insensible* distances, as they are far too small to be appreciated or taken cognizance of by the senses.

I may overcome the marble's cohesion by pulverization, or pounding, to a still greater extent; but even if I reduce it to the condition of a most impalpable powder, I cannot convert it into any thing but marble, although it is made up of two substances, carbonic acid and lime, which must be held together by some force quite independent of cohesion; seeing that the destruction of the latter does not enable them to be separated from each other.

To sum up, then, all that we have demonstrated respecting cohesion, it may be defined as that attractive force which, acting at insensible distances between particles of similar natures, keeps them firmly together; in the instance just cited, it joins two particles of carbonate of lime together, but not a particle of carbonic acid to another of lime in order to form the carbonate; this being effected by another force, named chemical attraction or affinity.

The marble falling on the ground breaks into pieces, and a fragment is thrown into a dish of sulphuric acid; effervescence immediately takes place, from the escape of carbonic acid, and a total change of composition ensues; the sulphuric acid uniting with lime, in order to form sulphate of lime, or plaster of Paris. This acid is just as securely attached to the lime as the particles of marble or carbonate of lime were attached to each other; not, however, by cohesion, but by chemical attraction or affinity.

It appears that sulphuric acid and lime possess a greater tendency for uniting with each other than carbonic acid and lime; or, to speak figuratively, lime selects or *elects* the sulphuric acid, by preference, hence this is an instance of *elective* affinity. As only one compound (sulphate of lime) is formed, the elective affinity is said to be single, and single decomposition is said to have occurred; but if two compounds had been formed, then we should have had an instance of *double* elective affinity, and *double* decomposition; as an example of the latter, I mix nitrate of baryta with sulphate of soda, when, owing to an interchange of elements, there result two compounds, nitrate of soda and sulphate of baryta.*

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* For instances of single and double elective affinity effecting single and double decomposition, see page 167.

LECTURE XXI.

INTRODUCTION TO ORGANIC CHEMISTRY—DIFFERENCES EXISTING BETWEEN THE STRUCTURE OF ORGANIZED AND INORGANIZED BODIES—DIFFERENCE BETWEEN ANIMALS AND VEGETABLES—PROXIMATE VEGETABLE PRINCIPLES.

ALTHOUGH it may be difficult, nay impossible, to offer a correct definition of the nature of life, I presume there are none of my young friends who will not perfectly comprehend me, when I inform them that things are divided into some which possess life, and others which do not. But nature has thought proper to withhold life from such bodies as are merely formed by the agency of those grand forces which regulate the inanimate portion of the universe. It has been decreed that life shall be associated with a peculiar and elaborate structure. Animals have parts adapted for touch, sight, taste, and smell; while structures for the circulation of blood, or sap, are common to both animals and vegetables. These parts or structures are called organs; hence arises the very natural distinction between organic and inorganic bodies, and hence the terms organic and inorganic chemistry.

So little do organized and inorganized things resemble each other, that a person unacquainted with chemistry would imagine them to be composed of elements altogether different, but such is not the case. The great Author of nature has confined himself in the formation of living beings to the use of a very few materials. Vegetables are chiefly composed of carbon, hydrogen, and oxygen; animals of carbon, hydrogen, oxygen, and *nitrogen.* This rule, however, is not universal, for there are some animal substances without nitrogen, and some vegetable ones with it; yet the distinctive character of animal matters in general consists in the presence of nitrogen. But we are not to regard these elements as the *only* ones which contribute to the formation of living or organized beings; vegetables have entering into their composition a great many different metals. Potassium and sodium enter so abundantly into the composition of land and sea plants, that we cannot but regard those metals as necessary constituents of the vegetable kingdom.

The blood of animals contains iron;—and calcium, the metal of lime, exists largely in bones, combined with oxygen and phosphorus, as phosphate of lime. Other metals still more uncommon have been affirmed to exist in certain vegetables. Coffee and tobacco are both of them said to yield traces of copper, and gold is reputed to have been discovered in tamarinds. Certain productions of the vegetable kingdom are incrusted with a coating of silicic acid, or flint: the shining surface of bamboo is composed of nothing but flint, and so likewise is the external glossy part of a straw. Two pieces of bamboo may even be made to yield sparks by striking them together; and an expert manipulator with the blow-pipe, will melt the flinty and alkaline matters of a common wheaten straw into a transparent bead of glass.

It was once imagined that the elements of organized and those of inorganized beings were united by forces altogether different, and that the ordinary chemical powers, as evinced by inorganic bodies, gave way in the formation of animals and vegetables to other forces of a different kind.

Since the science of chemistry has become more perfect, it is now known that the ordinary forces which determine the composition of inorganic things are also active in animals and vegetables, but their agency is very much modified by the principle of life; which does not supersede inorganic forces, but is merely superadded to them.

As all organized beings are either animals or vegetables, so the most natural division of this part of our science will necessarily be into animal and vegetable chemistry; a division, however, which participates in the imperfections of every other human invention, as will be hereafter perceived. We do not find it at all times an easy matter to decide whether an organized being belongs to the animal or vegetable world. It is easy enough to distinguish between an oak-tree and an elephant, and to determine that each belongs to a different organic kingdom; but it is not quite so easy to ascertain the relative position in creation of a sea-weed and a sponge: the latter is now universally allowed to belong to the animal creation, although apparently but little or nothing removed from the former, which is regarded in the light of a vegetable. As the precise line of boundary, then, between the animal and the vegetable world is still undefined, so must a division of organic chemistry into animal and vegetable be imperfect: nevertheless, it is useful, and still very generally followed.

One of the first subjects of wonder encountered by a person just entering upon the study of organic chemistry, is, that so many substances, of natures the most opposite, could ever have been made out of the same materials. What substances can be more apparently different than sugar, starch, and gum? Yet each is composed of three elements, carbon, hydrogen, and oxygen. This similarity of composition which exists between substances in the organic kingdom, enables us very often to change one into another. For instance, it is well known that a solution of sugar in water if exposed to the air at a certain temperature becomes vinegar, a change which is easily intelligible to a person who knows that they are both composed of the same elements united in different proportions.

Although we may sometimes effect changes on organic principles, as, for instance, in the case of sugar, yet we can in no instance make them by an artificial admixture of their elements. Neither sugar, starch, nor gum can be made artificially by any combination whatsoever of hydrogen, oxygen, and carbon; these elements can only be joined in the requisite manner by the agency of life, and in this lies the great distinction between organic and inorganic bodies.

The chemistry of inorganic substances is so well known, that we classify them in a scientific manner; that is to say, according to their chemical composition; but it is only within the last few years that the same precision has been introduced into the department of organic chemistry. Formerly animal and vegetable principles were classified according to their external propeties; for instance, under the heads of oils, acids, alkalies, and neutral bodies: lately, a far more correct method of classifying them has been introduced, founded on their chemical composition; however, it is far too elaborate for our purposes.

Compound bodies may be regarded under two points of view; with reference to their ultimate and to their proximate composition. This remark applies to every variety of compound, whether inorganic or organic, but more particularly to the latter. I can take a portion of some plant, and resolve or decompose it into carbon, hydrogen, and oxygen, by which means I arrive at its *ultimate* composition, for carbon, hydrogen, and oxygen, being ultimate elements, cannot be further decomposed. Again, without carrying the decomposition so far, I can resolve the same vegetable parts into a few substances called proximate, such as woody fibre, sugar, starch, and gum; all of which are composed of carbon, hydrogen, and oxygen united in various proportions.

These proximate principles of vegetables I purpose saying something about, and yet not much, for I cannot conceal the fact that organic chemistry is one of the most difficult branches of the science, and before a person can be even moderately acquainted with it he must spend many years in its patient and unremitting study.

The proximate principles of vegetables may be divided into acids, alkalies, and those which are neither acid nor alkaline, and hence are termed neutrals. As a matter of convenience I shall describe the latter class first, and commence my description with the proximate principle termed *lignin.* This very learned term, lignin, only means woody fibre, and if any of my audience wish to see a specimen of this proximate principle, let them direct their eyes to the first piece of wood in the neighbourhood; or a purer specimen is afforded by a piece of linen. Although the wood of different vegetables appears so unlike in its nature, yet it is actually made up of the same chemical principle. In hard woods the lignin is very brittle, while in the form of hemp and flax it is so extremely tough and tenacious that it serves the purposes of making cordage and linen: different degrees of toughness and strength are not produced by any chemical difference of composition. This point being discussed, a person commencing the study of chemistry stumbles on another, and apparently a more valid objection; that different kinds of woods are possessed of different tastes, smells, and appearances; all this is true, but still, chemically speaking, there is only one kind of lignin, or woody fibre, which, serving as a receptacle for any substance that it may be the nature of the plant to secrete, must necessarily afford various appearances, tastes, and smells. The different kinds of firs secrete turpentine, which in a manner is absorbed by the woody tissue, and deposited between its fibres: hence deal-wood has the odour of turpentine, although the chemical composition of its lignin is similar to that entering into the composition of every other tree. All trees of *this* climate, and, indeed, the greater number in all climates, consist of wood possessing two different degrees of hardness, called, respectively, by carpenters, heart-wood and sap-wood, and by the scientific botanist duramen and alburnum. These two kinds of wood may be very nicely observed in a lignum-vitæ ruler, the light coloured portion of which is alburnum and the dark portion duramen. Both portions are made up of woody fibre, but the dark part, or duramen, is saturated with a substance called guiacum, a secretion of the plant. This guiacum is not of so permeating a nature as turpentine, and hence it is almost entirely deposited in the heart-wood, while turpentine pervades every part of the trunk.

Another very important proximate vegetable principle is gum, of which there are many varieties, differing considerably in the ratio of their chemical elements, and obtained from a great number of different plants. Gum Arabic is procured from various species of the acacia, more particularly the *Acacia Arabica*, *A. Nilotica*, and *A. Seyal*. Gum Senegal very nearly corresponds in nature and composition to gum Arabic, it is chiefly obtained from the *Acacia verek.* There are also plum and cherry-tree gums, both nearly, although not quite, similar in composition to gum Arabic. Gum *tragacanth* is yielded by the *Astragulus verus*, and differs from gum Arabic in not being soluble in water, but merely swelling up and forming a tremulous jelly.

Starch is a proximate chemical principle, very nearly allied in composition to gum, but if examined by the microscope, it is found to be much more highly organized than the former substance, consisting of little vesicles, or bags, inclosing a peculiar matter, to which has been applied the term *amydine.* Starch exists in many parts of different vegetables, more especially in the seeds of grasses,* and the tubers, roots, and trunks of certain other plants. Starch which we find employed by the laundress is chiefly obtained from wheat, but sometimes from potatoes: naturally it is colourless; but for certain purposes it is tinged blue by means of indigo. Arrow-root, tapioca, sago, and cassava are all varieties of starch, the uses of which are so well known that it is quite unnecessary for me to expatiate on them here. Arrow-root is obtained from the *Maranta arundinacea,* and derives its name from the circumstance that the expressed juice of the plant is useful in curing poisoned wounds. Tapioca and cassava are procured from the root of the *Jatropha manihot,* a most poisonous plant, and which in its natural state would certainly cause death, even if swallowed in very small quantities, but the virulent principle is destroyed by roasting, and the nutritive substances, cassava and tapioca, remain. Sago is obtained from the trunk of the *Sagus farinifera* and *Phœnix farinifera,* both species of palms. I have already mentioned that iodine and starch are respectively tests for each other, indeed, you have seen the experiment performed.* One of the most curious properties of starch is the facility with which it is converted into sugar by the operation of various causes. If I expose a solution of starch in water to the free access of air for a considerable time, I shall ultimately find that there has been generated a certain quantity of sugar. If I boil a similar solution of starch with a little sulphuric acid, this process is much facilitated, and the formation of sugar is more complete. The operation of forming sugar from starch by artificial means is one of some difficulty :

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* The term *grass* is here used in a botanical sense, including wheat, barley, oats, rice, and, indeed, all other grain.

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* Page 73.

nature, however, accomplishes the process with far greater ease, as is exemplified in the instance of germination, concerning which I shall speak hereafter.

The proximate vegetable principle, sugar, exists naturally in a great many vegetables, but for commercial purposes it is chiefly obtained from the sugar-cane. By artificial means sugar may be entirely freed from colouring matter, and when crystallized in this condition it becomes what is called white sugar-candy.

Of sugar there are many varieties, besides that which is derived from the canes and other kinds of analogous composition; there is sugar of grapes, sugar of manna, called mannite, sugar of liquorice, called glycirrhizine, and sugar of milk.

Gluten is another important vegetable principle, which exists largely in various kinds of grain, particularly wheat. Gluten can easily be prepared by the following process: take some wheaten dough and expose it to the action of a running stream of cold water, kneading it well all the time ; by this process, starch is washed away, and gluten remains, mixed, however, with another principle, termed vegetable albumen. Gluten is an exceedingly nutritive substance, and its prevalence in wheat accounts for the superiority of that grain as an article of food. It is gluten which imparts tenacity to paste, and enables bread to acquire its porosity.

Bread is made by mixing together flour, water, and yeast, and afterwards baking; the yeast causes the gluten to ferment, during which process carbonic acid, and alcoholic vapour are given off, which force their way through the mass of dough, and blow it full of little bubbles. It appears, then, that the immediate cause of the porosity or lightness of bread is the passage of gas through the substance of the dough. Carbonic acid gas is the usual agent, but not the only one. Sometimes confectioners are in the habit of mixing with the dough, for making very light pastry, sesqui-carbonate of ammonia, (smelling-salts) which substance, by the heat employed in baking, is either decomposed or driven off in vapour, puffing up the dough into a light spongy mass.

Such are the chief neutral vegetable principles; many others might be enumerated, but I do not think it worth while. Let us now turn our attention to a few of the vegetable alkalies. You remember my mentioning the alkalies ammonia, potash, soda, and lithia; these, not many years since, were the only ones of which chemists had any knowledge; but as the progress of discovery advanced, a class of alkalies altogether new dawned from the vegetable world. Some little period of time elapsed before their claim to be termed alkalies was admitted, and they were known by the cautious appellation of *alkaloids*, that is to say, substances allied, or similar to alkalies: their alkaline claim is now, however, universally recognized. Few chemical discoveries have conferred so much benefit upon the practice of medicine, as that of the vegetable alkalies. Cinchona-bark has been employed for the purpose of curing agues ever since the commencement of the seventeenth century: but in order to prove of service, this drug must be given in doses which are so large that they often produce great sickness, and other unpleasant effects. Now the activity of cinchona-bark* is concentrated in the alkalies *quina cinchonia* and *aricina*, all the rest being inert matter, and offending the stomach. Chemistry has taught us how to separate these alkalies, and to give them apart from inert woody matter, by which means their administration is much more easily accomplished, and their action rendered far more effective. Again, that very valuable drug, opium, derives its beneficial qualities entirely or *almost* entirely, from an alkali called morphia, which chemistry has taught us how to extract, and to administer in several advantageous forms.

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* Peruvian or cinchona-bark was introduced into Spain by Count Cinchon, A.D. 1632. Sometimes it is called Jesuits' bark, because the Jesuits strenuously advocated its use.

The vegetable acids are exceedingly numerous, and some of them are very important substances. The best known and most useful are acetic acid, which, when diluted and mixed with various impurities constitutes vinegar; citric acid, which exists in lemons, and imparts to them their sour taste; tartaric acid, which is obtained from the bitartrate of potash, or cream-of-tartar, a substance that deposits in wine-casks; and oxalic acid, which is found in many vegetables, particularly in the wood-sorrel, (*Oxalis acetosella*,) combined with potash in the form of binoxalate of that akali. The substance purchased in the shops under the name of salt-of-lemons, is in reality binoxalate of potash, and is much employed for removing ink-stains from linen. Oxalic acid is used by chemists as a test for lime; for this purpose either a solution of the uncombined acid may be employed, or some of its combinations with potash or ammonia; oxalate of ammonia is generally preferred. With lime it throws down a copious and very insoluble white precipitate, and hence the efficiency of carbonate of lime, (chalk,) as an antidote for this poison. Besides the vegetable acids already enumerated, there are many others which I shall pass over, as they are not very well known, neither are they applied to any very useful purposes.

A very large and important class of substances derived from both the vegetable and animal kingdom, are the oils; usually considered to be neutral bodies, yet they seem to possess the properties of acids, at least, the greater number of them: oils are divided into fixed and volatile, or expressed and essential. If I drop a little almond-oil upon a piece of paper, and attempt to remove the stain by holding it before the fire, my endeavours will be fruitless, because almond-oil is a fixed oil, and will not readily evaporate; but if I hold before the fire a piece of paper soiled with otto, or oil-of-roses, oil-of-lavender, of turpentine, of lemons, of peppermint, of cinnamon, of carraways, and many others, the stain will speedily disappear, the oil flying off in very pungent vapours; hence the latter are termed volatile oils, or sometimes *essential oils*, from their property of readily dissolving in spirit, and forming liquids, called essences. It is owing to the presence of essential oils that plants derive their various odours, and these oils may, in many instances, be separated by the process of distillation; but there are some of so fleeting and subtile a nature, that the heat necessary for conducting the process of distillation entirely destroys them; for instance, no distillation, however carefully conducted, has hitherto accomplished the separation of the oil-of-jasmine, which is extracted in a very different manner; jasmine flowers are moistened with almond oil, and then exposed to great pressure, which squeezes out the oil-of-jasmine mixed with oil-of-almonds. The greater number of oils, both fixed and volatile, are compounds of carbon, hydrogen, and oxygen, but a few are composed of carbon and hydrogen alone; as examples of these, I may mention oil-of-lemons and oil-of-turpentine, both of which, so far as relates to chemical composition and properties, are precisely similar. The liquid sold under the name of scouring-drops, is merely distilled oil-of-lemons, and is much employed for the purpose of removing stains of grease from silk and linen. The substance named camphor, is a solid volatile oil, which is obtained very plentifully from various parts of the *Laurus camphora*, a native of Japan.

Volatile or essential oils are capable of being dissolved to a very limited extent by water, to which liquid they impart their peculiar tastes and smells. Rose, cinnamon, lavender, and peppermint-water are all of this nature.

Very nearly allied in composition and properties to fixed oils are substances of a resinous or bituminous nature. Common resin is obtained from various species of fir, where it exists in combination with oil-of-turpentine, and remains after the latter has been separated by the process of distillation. During the separation of turpentine from resin, a portion of the latter is decomposed into a black, viscid, substance, called tar; and pitch is merely tar from which the volatile particles have been driven off by long boiling.

Respecting the kingdom of organic nature to which the substance wax should be referred, there has been a dispute; some persons regarding it as a vegetable, and others as an animal principle. It is now, however, generally allowed, that although wax does occur as a natural vegetable production, yet this vegetable substance differs from bees'-wax, the nature of which is considerably modified by the digestive organs of the bee; indeed, the fact has been demonstrated, that bees fed on sugar alone will nevertheless produce wax.

The curious substance termed caoutchouc, or India-rubber, cannot be said to resemble any other body which chemistry makes known; but in the nature of its components it approaches the resins. India-rubber is chiefly obtained from the *Hævea*, caoutchouc, and *Jatropha elastica*, natives of South America, and of the *Ficus Indica* and *Artocarpus integrifolia*, which grow in the East Indies; but many other vegetables yield it in smaller proportions. It exists both in the mulberry and lettuce, and, indeed, in *every vegetable* on which the silk-worm thrives; hence it has been imagined that the tenacity of silk may, in some measure, depend on the presence of India-rubber.

Under the head of bituminous substances are included naphtha, petroleum, asphaltum, and the different varieties of pit-coal, besides some others. Naphtha is a colourless liquid, possessing a very strong odour, and occurring as a natural product in many parts of the world, more particularly Italy, the Grecian isles, the banks of the Caspian, and Persia. In the latter country it supports the perpetual flames of the Persees, a set of enthusiasts who adore fire as a deity, and on this account are termed fire-worshippers. Naphtha is composed wholly of carbon and hydrogen; hence, amongst other uses, it is employed to preserve the metals sodium and potassium.*

Pit-coal is the remnant of vast forests, which were overwhelmed by some grand convulsion of nature, and covered by strata of different kinds. Since which period they have been undergoing a gradual decomposition, subject in the meantime to an immense pressure from the superincumbent mass. Some specimens of coal are so perfect that the forms of the original vegetable fibres, and also of the leaves, are not yet destroyed; so that even now, after the lapse of many ages, it is still possible to ascertain that the greater quantity of coal has been formed from gigantic ferns.

Infinitely superior as beings of the animal world appear to all other forms and things in creation, their excellence is not the result of properties implanted in the primary elements which enter into their formation, but depends upon the principle of life implanted in them by the Deity. Vegetables are chiefly composed of hydrogen, oxygen, and carbon, united in various quantities, in order to form a limited number of proximate principles. Animal tissues, in addition to the three bodies just mentioned, contain a large proportion of nitrogen; but other substances enter into their composition in small quantities. The parts of the body of an animal may be divided into solids and fluids; the latter being, for the most part, water, which composes nearly five-sixths by weight of the human body.

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* See p. 223.

Of the *proximate* principles which enter into the formation of animals, some are also found in the mineral world, whilst others are necessarily connected with animal organization.

The bones are composed of a peculiar substance termed by chemists, gelatine, holding together little particles of phosphate and carbonate of lime: gelatine, when moist, is quite elastic; but masses of the carbonate and phosphate of lime are brittle; consequently, it is to the union of these three substances that we must attribute the admirable strength of bone; which is not so brittle as to be readily broken, and yet hard enough to support the weight and to withstand the violent action of the body without bending or losing its form.

I cannot pass over the description of bone without noticing an all-wise and admirable provision of nature against the different necessities of infancy and age. In children, the bones contain their greatest relative quantity of gelatine; hence they are not hard and brittle but tough and elastic, by which means children are protected against many of the evil consequences that would otherwise arise from the falls and blows to which their sportive gambols continually expose them: gelatine, moreover, is susceptible of that developement which it is necessary for every part of the body to undergo, and it is not until the period of growth ceases, and the hilarity of youth has yielded to the gravity of sober manhood, that the deposition of carbonate and phosphate of lime is complete. A few more fleeting years pass away, and then arrives the period of old age, when nature, gradually preparing for the approach of death, removes a portion of gelatine, and leaves the compounds of lime in excess. It is then that our poor frail bodies must avoid all blows and shocks; we necessarily grow cautious and circumspect; recollections of mortality crowd thickly upon the mind; the consciousness that so much care is necessary for our bodily safety admonishes us of our closing earthly career; and proclaims, in language which cannot be misunderstood, that we have approached the confines of another world.

As animals are not capable of generating the elements of which those compounds of lime are formed, it follows that they must be taken into the stomach with articles of food, chiefly solids: in the infant state, however, no solid food is taken, although there is an absolute necessity for a *certain* quantity of phosphate of lime to enter into the formation of infant bones: —the substance being naturally of an insoluble nature, one would not imagine that it existed in milk, but nature has accomplished her purpose by means of an acid, termed lactic, which is endowed with the property of rendering phosphate of lime soluble.

Gelatine exists in many other parts of animals besides bones. It is found abundantly in skin, tendons, hoofs, and horns: glue, isinglass, size, and jelly are examples of this animal proximate principle, gelatine. The properties of gelatine are to dissolve when soaked or boiled with water, forming a jelly, and to yield precipitates with the tannic and gallic acids, named tannate and gallate of gelatine; on this latter property depends the manufacture of leather, which substance is, chemically speaking, a tanno-gallate of gelatine. Leather is formed by immersing skins, previously deprived of their hair and oil by lime, in a strong infusion of oak-bark, which contain the two acids in question; tanno-gallate of gelatine, or leather, is the result. Lately the process of tanning has been conducted without oak-bark, the substance catechu being used in its stead.

Gelatine is a very nutritive principle, and forms the basis of some of our most valuable articles of food. It is seldom procured from bones, because water at the ordinary boiling temperature, that is to say at two hundred and twelve degrees, is incapable of removing it from the accompanying salts of lime; but if the boiling point be increased by an increase of pressure, then we may obtain gelatine from bones as well as from other more common sources. There is an instrument much used for the purpose, called Papin's, digester; its agency depending upon an elevation of the boiling point of water far above the usual degree. It is merely a very thick metallic vessel, supplied with a safety valve, which is pressed down with a degree of force proportionate with the elevation of the boiling point required. There is another method of obtaining gelatine from bones: the compounds of lime may be dissolved away by weak hydrochloric acid, leaving the gelatine isolated and capable of forming a solution with water by ordinary means. Gelatine as it exists in bone possesses a remarkable power of resisting decay; consequently if at any time a civilized nation should be threatened with famine, it is probable that its inhabitants would set about the extraction of gelatine from bones, where it is stored up in security, but capable of being obtained in any case of emergency. Whilst on this topic I will mention an anecdote, but for its truth I cannot vouch. It is affirmed that some French philosophers, having found a bone of some creature which existed before the deluge, came to the extraordinary determination of regaling themselves on antediluvian soup, which singular project was carried into effect by extracting the gelatine in the way I have already mentioned.

Albumen is a proximate principle which is found in very many animal fluids and solids, but more particularly in the blood and in the white of eggs, particularly the latter. Albumen may be resolved, like gelatine, into carbon, hydrogen, oxygen, and nitrogen, and may be known from all other substances by the peculiar effects of heat, which converts it into a solid, as is well exemplified by the boiling of an egg. Albumen has the property of being precipitated by various re-agents, particularly the bichloride of mercury and salts of copper. On this peculiarity depends its efficacy as an antidote to those substances when they may have been taken as poisons.

Fibrin is an animal principle, which is chiefly found in the muscles or flesh of animals and in the blood. It may be procured by various methods, but most easily by washing clots of blood until all the colouring matter is removed.

The animal acids are very numerous, but none of them are of sufficient importance to merit a particular description on such an occasion as this. Among the principal I may name the lithic or uric, purpuric, rosacic, and formic acids.

Animal bodies contain great quantities of oils and fats, possessing various degrees of hardness and liquidity. Many of these are employed as articles of food, and others are extensively used in the arts. The various kinds of soap are combinations of alkalies with different acids procured from oils and fats. Soaps may be formed either with animal or vegetable oils. In England, animal oils and fats are cheaper than those from the vegetable kingdom; hence we use them in preparing soap; but in Spain, where there is such an abundance of olive-oil, *this* is used for soap-making. Animal oils are chiefly composed of two proximate principles, oleine and stearine; the greater number of vegetable oils, of oleine and margarine, all of which, by the action of potash or soda, may be converted into oleic, stearic, and margaric acids; which are no sooner formed than they unite with the alkalies, constituting ole*ate*, margar*ate*, and stear*ate* of potash or soda, all different varieties of soap. Soap made from tallow and soda is an oleo-stearate of that alkali, and chemically speaking, is a salt.

Organic bodies are subject to a variety of intestine changes, commonly known by the name of fermentations; these are usually divided into the saccharine, vinous, acetous, and putrefactive. That starch can be converted into sugar I have already mentioned, and on this depends the art of malting. Barley, in common with other grain, contains a large quantity of starch, which is laid up as in a magazine for the young plants future nourishment. The operation of malting causes the grain to germinate, during which process starch becomes converted into sugar.

But malting is only one instance of germination; a branch of vegetable physiology so important that it demands a more extended share of our attention. The term germination very prettily expresses its own meaning: the first bursting forth of a dormant embryo from the seed. Vegetables may be divided into those which bear flowers and those which do not. Only the former possess seeds, and hence they alone can be susceptible of germination, properly so called. The seeds of flowering plants are either possessed of one lobe or two, a fact of so much importance in botany, that upon its consideration is founded a divison of flowering plants into two great classes;—monocotyledons, or those whose seeds have but one lobe; and dicotyledons, or those the seeds of which have two or more.

Germination proceeds somewhat differently in monocotyledonous from what it does in dicotyledonous seeds, at least, so far as the mechanism of the operation is concerned; but the chemical changes are similar in either instance. The skin, or covering of a seed, is composed of at least three membranes, which, taken collectively, are called the testa; this testa incloses the seed, properly so called, which is made up of a substance called albumen, and the embryo; or, in some cases, of the embryo alone; which latter is furthermore divided into radicle, plumule, and cotyledon, or cotyledons, as the case may be. If we bury a dicotyledonous, or two-lobed seed, a few inches under the earth's surface, and all circumstances be favourable, the following changes ensue. By the absorption of moisture it swells and the two lobes separate, the radicle descends, the plumule ascends, and with it the two cotyledons, which are to be considered as rudimentary leaves: during the whole of this period there has been going on a chemical operation;—oxygen has been absorbed from the atmosphere to combine with carbon of the starch, and form carbonic acid, which has escaped, leaving sugar behind: in other words, sugar only differs from starch (as far as regards composition) in containing less carbon. Starch is not very soluble, and hence could not have been conveniently appropriated by the young plant to its own uses; sugar, however, is soluble, and is in every respect well calculated to answer the purpose of nourishing the growing plant. Very low temperatures are unfavourable to germination, and hence it will not take place in the winter; high temperatures are also unfavourable to the process, by destroying the vitality of the seed. Both these statements are exemplified in the operation of malting. The grain is made to pass through four distinct stages, called steeping, couching, flooring, and kiln-drying; the object of which being, first, to set up artificial germination, and thus convert starch into sugar; then, to destroy all vitality of the germ before it has had time to appropriate to its own uses the sugar generated. The grain is first steeped in water for about two days, when it absorbs moisture, softens and swells considerably; after which it is removed to the couch-frame, where it is laid up in heaps of thirty inches in depth for from twenty-six to thirty hours. In this situation the grain becomes warm, and acquires a disposition to germinate; but as the temperature in such large heaps would rise very unequally, and germination consequently be rapid in some portions and slow in others; the process of flooring is employed. This consists in placing the grain in layers, a few inches thick, on large, airy, but shaded floors, where it remains for about twelve or fourteen days; in short, until it is ascertained that the conversion of starch into sugar has been completed. During all this time it is frequently turned to prevent a matting together of the young germs; and now the period arrives when the maltster wishes to destroy that vital principle which has been brought into action through his agency. The young germ, hastening to leave its narrow cell, and to sprout forth into the world, has been busily preparing food for its infant growth, until its fully developed root should be able to gather nourishment from the earth: but its busy preparations receive a sudden check. The sprouting seeds are removed to a kiln; where a high degree of temperature soon destroys the vital principle, and the elaborated sugar, intended as food for the young plant, is appropriated to the uses of rapacious man.

It is well known that intoxicating drinks result from the fermentation of different mixtures containing sugar: thus grape-juice contains a large proportion of sugar, and when fermented becomes converted into wine. Now the intoxicating quality of wines, beer, cider, and indeed all strong drinks, depends upon the prescence of alcohol, also called spirits-of-wine. Alcohol is very volatile, and therefore may be procured from various liquors by the process of distillation: rum, brandy, gin, and hollands all consist essentially of the same substance, alcohol, differently flavoured with various impurities.

It was once doubted whether alcohol actually existed in wine, or whether it was formed by the application of heat during distillation; the doubt, however, no longer exists; for alcohol may be procured without distillation at all, although this process is usually resorted to for the sake of convenience. Fermented liquors consist of water, alcohol, and colouring matter: the latter may be removed by various means, and then there is a very easy method of separating alcohol and water, without the aid of distillation. Here is a little port-wine, to which I add some solution of *di-acetate* of lead,* and immediately there falls a very copious precipitate of colouring matter, leaving the alcohol and water floating above. I now separate the colourless fluid from the colouring matter, by means of a filter or strainer of blotting-paper; and this being done I add to it some dry and hot carbonate of potash, commonly called salts-of-tartar, and very soon we shall observe that the fluid will be divided into two layers, one above the other; the upper layer consists of pure alcohol, and the under layer of water, in which is dissolved carbonate of potash.

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* Commonly called Goulard's extract.

The experiment that you have just witnessed may very often be turned to good account for estimating the strength of wines. Instead of carbonate of potash I might have used a substance termed chloride of calcium, which indeed is still more effective. There is no body so generally available for removing water, as chloride of calcium, and with this intention it is very extensively employed in chemistry.

In ascertaining the strength of wine, a preliminary operation was necessary to separate the colouring matter, but if I had wished to ascertain the strength of brandy, rum, or gin, all of which contain but very slight traces of colouring matter, then I might have applied the carbonate of potash or chloride of calcium at once. It is satisfactorily proved, then, that alcohol is not formed during the process of distillation, but already exists in fermented liquors as a result of the vinous fermentation. Alcohol is also generated during the preparation of bread, and if the oven be supplied with a proper apparatus, this alcohol may be collected. Some persons speak of the *panary* fermentation, *panis* meaning bread, but it is at most but a modification of the vinous. It has been attempted to separate this alcohol from bread, and collect it for commercial purposes; indeed, the project has been tried on a very large scale, and, to a certain extent, with success;—that is to say, alcohol could be collected easily enough, but in order to do this it was found necessary to bake the bread so dry that no one could eat it: hence, the scheme was abandoned, and much (I should imagine) to the satisfaction of every rightly thinking member of the community; for no one who reflects on the ease with which alcohol is obtained from other sources, and who witnesses the hurried strides with which the victim of a desire for spirituous liquors hastens towards his early grave, would feel pleasure in knowing that bread, the staff of life,—the standard food of man, was obliged, by a set of greedy speculators, to yield a fluid which, when abused, has been, and still continues to be, the greatest bane of society.

Very nearly allied to alcohol is the class of substances termed ethers. Few words have had the misfortune to be applied in such a loose and indefinite sense as the word ether. The poets use the term ether for the atmosphere, or something far beyond the atmosphere, and even beyond the universe itself. Natural philosophers sometimes make use of the same expression to indicate an imaginary fluid, which, when agitated and impelled into waves or undulations gives rise to the sensation of light; and, lastly, the same term, ether, is applied to certain volatile fluids, which are formed by the action of various acids on alcohol;—in which sense I now intend using it myself. If sulphuric acid be distilled with alcohol, we obtain as a result sulphuric ether; if nitric acid, nitric ether; if hydrochloric acid, hydrochloric ether: in short, there are but very few strong acids which are not capable of forming ethers with alcohol, and the process is termed etherification. The composition of ethers produced by different acids varies a good deal, and consequently the theory of etherification must be different in every case. There are many ways of regarding the mode in which the elements which constitute ethers are united together; but it is in general imagined that they are modifications of an imaginary base, which has been termed etherine. Etherine consists of carbon and hydrogen, in the following ratio:—

$$\text{Etherine}\begin{cases}\text{4 Carbon.}\\ \text{4 Hydrogen.}\end{cases}$$

It would neither be very instructive nor very easy to go through the process of making the different ethers: none of them are of much importance, with the exception of sulphuric ether, but the latter demands a little attention. On distilling a mixture of alcohol and sulphuric acid in a glass retort, by the heat of a spirit-lamp, and adapting a cooled receiver, sulphuric ether comes over. It is a liquid possessing a very peculiar odour; having a great tendency to fly off in vapour, and not very miscible with water. The theory of the production of sulphuric ether has been variously stated. The account which was formerly given of the process is the following: that alcohol was composed of one equivalent of the substance etherine and two of water; and sulphuric ether, of one of etherine and one of water; that sulphuric acid abstracted one of water, and ether passed over. This theory has been a little modified, but even at the present time it is essentially true, the result being as I have mentioned; but in the space elapsing between the first addition of sulphuric acid and the evolution of the ether, there is generated an intermediate substance, termed sulpho-vinic acid, which, however, is no sooner formed than the heat necessary for the experiment destroys its evanescent existence; therefore we need not take much account of it in explaining the formation of sulphuric ether.

The acetous fermentation is that which gives rise to the formation of vinegar or acetic acid, and the putrefactive fermentation is only another term for decay, consisting in the change of organic principles, into the more simple forms of inorganic existence.

As the complicated structure of an animal or a plant owes its formation to the mysterious agency of life, so it is only by the same life that its preservation is maintained. When deprived of this, the inorganic forces exercising their full sway, again resolve it into simple forms:—it withers and decays. This change, then, is no less certain than death itself; sooner or later it awaits us all, and every living thing.

The giants of the vegetable world; the stately cedar, and the sturdy oak; the pine,—which braves the rigours of the Alpine snow; and the towering palms,—which greet a burning sun, await their doom, no less than the lowly daisy or the spreading moss:—they all must die! The majestic elephant,—which shakes the earth on which he treads; the mighty whale,—revelling to-day in all the plenitude of power—the lion, the tiger,—themselves the harbingers of death, yield alike to the fate of the sparrow or the worm. Even the beauty of the human form, impressed as it is with the image of God,—and shining in grand pre-eminence, beyond the creatures of mere earthly mould,—beaming with all the graces of youth, or standing erect in manhood's dignity;—this too must die! In fine, it is decreed that death shall be the fate of every living thing,—and after death decay: that the principle of life, once implanted, shall cease to maintain its sway; that the little atoms, which, under its guidance, budded forth into leaves and flowers, or shone in the statelier majesty of animated forms, shall resolve themselves again into simpler states;—and, no longer directed by the principle of life, shall roam like little wanderers on creation's broad expanse.

In contemplating the process of decay or putrefaction, the mere common observer experiences no sensations but those of disgust; with the chemist it is far otherwise; *he* does not regard death as a calamity—neither do ideas of destruction ever enter his mind. *He* sees the elements of former beings springing up into new states of existence, and teeming with all the freshness of infant life: *he* recognizes in all those changes the workings of a heavenly hand; and remembers, with fond satisfaction, that the Being who condescends to dissolve and re-arrange the elements of a lowly plant or creeping worm, will never cease to minister to the proper wants, or neglect the guidance of that most noble of all earthly beings,—into which he himself has breathed the breath of life, and implanted a conscious and never-dying soul.

When surveying the vast field of organic chemistry, the mind loses itself in the multiplicity of combinations which we see taking place around us. Myriads of little atoms ever combining, separating, and recombining, seem to treat the inquisitive philosopher with playful disdain, and to defy his curiosity. We have hitherto followed them at an easy pace, without much fatigue and with some little amusement; but now they run wild in their gambols, and to keep pace with them might cause us some fatigue:—I bid them all farewell! and you,—my young friends,—I also bid farewell;—for my Lectures on Chemistry are finished. We entered upon the study of our science with sportiveness and mirth; but towards the conclusion of our labours we have been compelled to become more serious, and to use language more in accordance with the nature of our subject. As a young lion torn from the forest is tame and playful, allowing caresses, and joining in every frolic, so we found chemistry; but as it grew up to its full size and formidable strength,—it became a thing no longer to be played with;—demanding all care, attention, and respect. If I have grown dull in the prosecution of my task; if I have used language too difficult or too unpleasing; in short, if you have been less interested by the termination than by the commencement of my Lectures, do not judge me too harshly, I beseech you, but attribute some of these defects to the increasing difficulties of my subject.

And now accept my best wishes for the prosperity of our little institution: if my labours should be deemed of any service in promoting its advancement I certainly will come again, and lecture on some other subject. Once more I bid you farewell.

THE END.

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